LONDON-WEST MIDLANDS ENVIRONMENTAL STATEMENT

Volume 5 | Technical Appendices

CFA23 | Balsall Common and Hampton-in-Arden

Flood risk assessment (WR-003-023)

Water resources

November 2013

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Appendix WR-003-023

Environmental topic:	Water resources and flood risk assessment	WR
Appendix name:	Flood risk assessment	003
Community forum area:	Balsall Common and Hampton-in-Arden	023

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1 Introduction

1.1 Structure of the water resources and flood risk assessment appendices

1.1.1 The water resources and flood risk assessment appendices comprise six parts. The first of these is a route-wide appendix (Volume 5: Appendix WR-001-000).

1.1.2 Additional specific appendices for each community forum area are also provided. For the Balsall Common and Hampton-in-Arden area (CFA23) these are:

- a water resources assessment (Volume 5: Appendix WR-002-023);
- a flood risk assessment (i.e. this appendix);
- a hydrology report for the River Blythe catchment (Volume 5: Appendix WR-004-016)
- a hydraulic modelling report for the River Blythe and Bayleys Brook (Volume 5: Appendix WR-004-017); and
- a hydraulic modelling report Bayleys Brook (at Marsh Farm and Lavender Hall Lane), the River Blythe Bypass, Shadow Brook and Hollywell Brook (Volume 5: Appendix WR-004-018).

1.1.3 Maps referred to throughout the water resources and flood risk assessment appendices are contained in the Volume 5 water resources map book.

1.2 Scope of this assessment

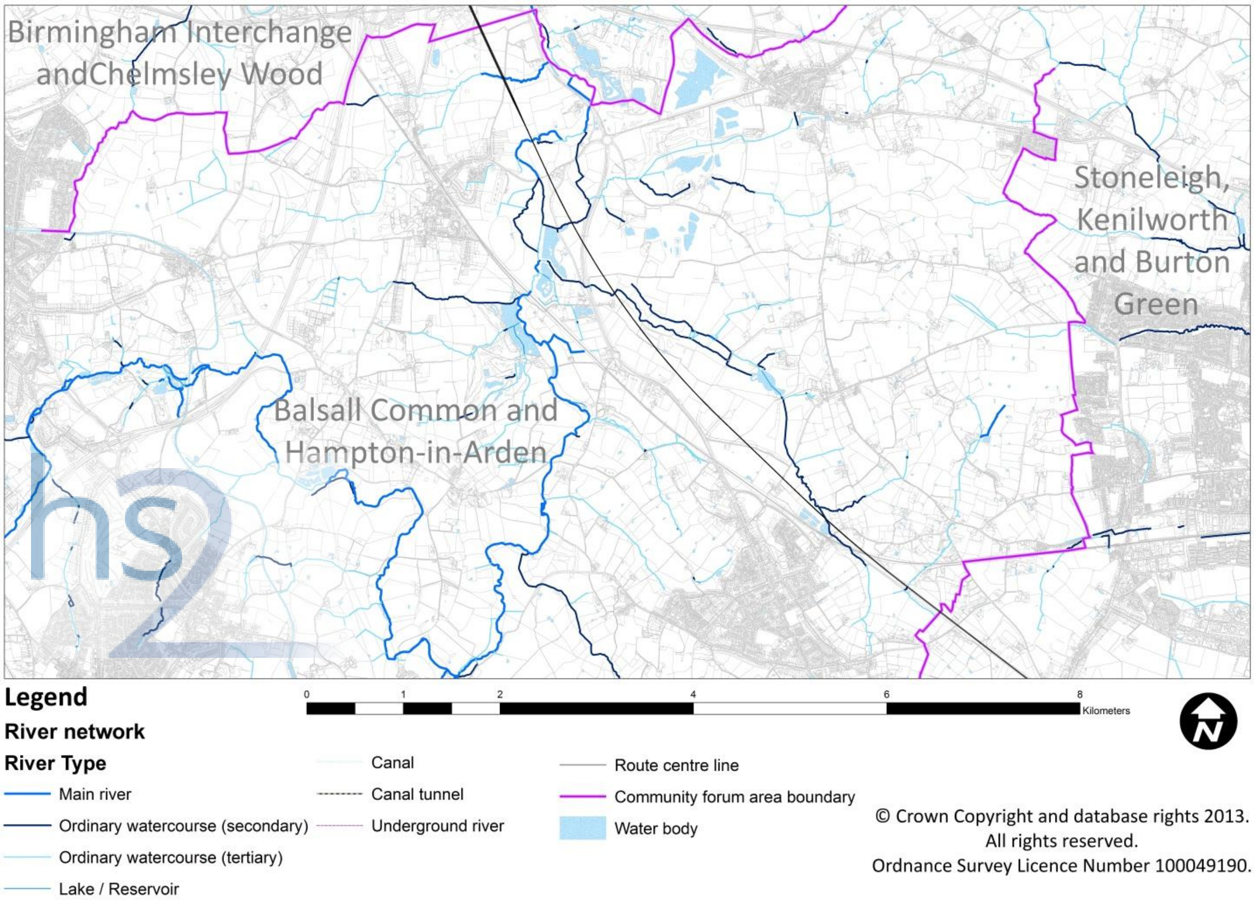
1.2.1 This flood risk assessment (FRA) considers the assessment of flood risk in the Balsall Common and Hampton-in-Arden CFA. This FRA is based on the Proposed Scheme as shown in Volume 2: Map book CT-06. Its purpose is to document how flood risk has been assessed and managed at this stage of the project's development so as to inform the hybrid Bill. It can be anticipated that the details of flood risk management will develop further as the project proceeds through later stages of design. The assessment has been carried out in accordance with the requirements of the National Planning Policy Framework (NPPF)[1], which aims to prevent inappropriate development in areas at risk of flooding and to ensure that, where development is necessary in areas at risk of flooding, it can occur without risk to the development or to third parties.

1.3 Location

1.3.1 This report focuses on CFA23 Balsall Common and Hampton-in-Arden. The area of consideration is shown in Figure 1.

1. Department for Communities and Local Government (2012) *National Planning Policy Framework*

Figure 1: Balsall Common and Hampton-in-Arden CFA23



2 Flood risk assessment methodology

2.1.1 The aim of this FRA is to assess the risk of all forms of flooding to and from the development. A risk-based methodology has been adopted through the application of the source-pathway-receptor (SPR) model.

2.2 Source-pathway-receptor model

2.2.1 Flood risk is assessed using the source-pathway-receptor model. In this model, individual sources of flooding within the study area are identified. The primary source of flooding is rainfall, which is a direct source in the short-term (surface water flooding) and can lead to flooding from watercourses (river flooding) and overloaded man-made collection systems (sewer flooding) in the short or medium term. Stored rainfall, either naturally in below ground aquifers and natural lakes or artificially in impounded reservoirs and canals can lead to flooding when the storage capacity of the system is exceeded. A final source of flooding arises from tidal effects and storm surges caused by low pressure systems over the sea.

2.2.2 The identification of the flooding source and pathway is based on a review of local conditions and consideration of the effects of climate change (CC).

2.2.3 For there to be a risk of flooding at an individual receptor there must be a pathway linking it to the source of flooding. The pathways within the study area are assessed by reviewing national datasets that show the spatial distribution of flood risk. Taking this into account, the associated magnitude of risk is then categorised.

2.2.4 Receptors include people, properties, businesses, infrastructure, the built and the natural environment which is within the range of the flood source, and is connected to the source of flooding by a pathway. The Proposed Scheme includes all associated temporary and permanent infrastructure.

2.2.5 This FRA presents baseline (current day) flood risk and post-development flood risk as a result of the Proposed Scheme. Areas of interest are identified through comparison of the national spatial datasets with the design drawings. Where a risk is identified, mitigation is proposed in line with recommendations in the NPPF.

2.2.6 Existing development within the study area is identified using Ordnance Survey (OS) mapping information and a high level assessment has been undertaken to identify receptors that are within or in close proximity to an area of flood risk via pathways. The vulnerability of each receptor is classified using Table 2 of the NPPF Technical Guidance Document[2].

2.2.7 The assessment then considers the vulnerability of the receptor with reference to the flood risk category of the source using Table 3 of the NPPF Technical Guidance Document and assesses whether the Proposed Scheme has any potential to influence or alter the risk of flooding to each receptor. The Proposed Scheme is committed to ensuring that there is no adverse effect on the risk of flooding to third party receptors, and therefore, where such potential exists, mitigation is proposed based on further analysis.

2.Department for Communities and Local Government (2012) *National Planning Policy Framework Technical Guidance*

2.2.8 The FRA has been written to demonstrate the relative change in flood risk as a result of the Proposed Scheme. Whilst all change in risk status is highlighted, the focus of this document is on the change in risk status to identified local receptors, particularly existing infrastructure.

2.3 Flood risk categories

2.3.1 The level of flood risk is categorised by assessing the design elements against the datasets for each source. A matrix showing the flood risk category associated with each flooding source is presented in Table 1.

Table 1: Flood risk category matrix for all flooding sources

Source of flooding	Flood risk category				
	No risk	**Low**	**Medium**	**High**	**Very high**
Watercourse[3]	-	Flood Zone 1	Flood Zone 2	Flood Zone 3a	Flood Zone 3b
Surface water / overland flow[4]	No FMfSW	FMfSW <0.3m for 1 in 200 year event	FMfSW >0.3m for 1 in 200 year event and FMfSW <0.3m for 1 in 30 year event	FMfSW >0.3m for 1 in 30 year event	-
Groundwater[5]	-	Very low-low	Moderate	High-very high	-
Drainage and sewer systems[6]	No sewer in vicinity of site	Surcharge point >20m from site and no pathways	Surcharge point within 20m of site and restricted pathways	Sewer network crosses site and pathways exist	-
Artificial sources[7]	Outside of inundation mapping / no pathway exists	Within inundation mapping / pathway exists	-	-	-

2.4 Exclusions and limitations

2.4.1 Temporary works have not been assessed unless they are of a significant scale compared with the post-construction scheme or are subject to or pose a significant flood risk or change in risk.

2.4.2 The assessment has been carried out in accordance with the requirements of the National Planning Policy Framework (NPPF)[8], which aims to prevent inappropriate development in areas at risk of flooding and to ensure that, where development is necessary in areas at risk of flooding, it is safe without increasing flood risk elsewhere.

3. River flood risk taken from the Environment Agency Flood Zone mapping or hydraulic modelling carried out for this FRA.

4. Surface water flood risk taken from the Environment Agency Flood Maps for Surface Water (FMfSW).

5. Groundwater flood risk taken from local flood risk assessment reports.

6. Identified using the Severn Trent Water's assets network.

7. Risk from reservoir flooding identified using the Environment Agency Reservoir Inundation mapping, canal flooding taken from identifying proximity of the Proposed Scheme to canals from Ordnance Survey mapping.

8. Department for Communities and Local Government (2012) *National Planning Policy Framework*.

2.4.3 No existing hydraulic models existed within this area, and a number of discrete hydraulic models were constructed. These are detailed in the accompanying hydraulic modelling reports (Volume 5: Appendices WR-004-017 and WR-004-018). The models and flood extents should only be viewed in the context of assessing flood risk related to the Proposed Scheme.

2.4.4 This FRA (and accompanying appendices) and the associated hydraulic models will require updating as the design develops and a greater level of detailed data (e.g. topographical survey) become available.

3 Design criteria

3.1 Source of design criteria

3.1.1 This FRA has taken account of the following documents:

- NPPF;
- Highways Agency Design Manual for Roads and Bridges (1992)[9];
- National Sustainable Drainage Systems (SuDS) Working Group Interim Code of Practice (2009)[10];
- Water Resources and Flood Risk Technical Note: Flood Risk Assessment (see Volume 5, Appendix CT-001-000/2 Scoping and methodology report addendum); and
- CIRIA Report C689 - Culvert Design and Operation Guide (2010)[11].

3.1.2 The key design criteria applied to the project are summarised below.

3.2 Summary of principal design criteria

Flood risk to third parties

3.2.2 The design has set out to avoid significant increases in flood risk to third parties, as a result of the Proposed Scheme up to and including the 1% Annual Exceedence Probability (AEP) flood event plus an appropriate allowance for climate change (cc) which has been abbreviated to 1% AEP+CC within this report.

Climate change

3.2.3 Climate change allowance is in accordance with NPPF.

3.2.4 Increases in peak rainfall intensity and peak river flow as a result of climate change have been allowed for as per the period 2085 to 2115 as defined in Table 5 of the Technical guidance to the NPPF and shown in Table 2 below.

Table 2: Appropriate climate change allowance figures for rainfall intensity and peak river flow (extract from Table 5 in Technical Guidance of the NPPF)

Parameter	1990 - 2025	2025 - 2055	2055 - 2085	2085 - 2115
Peak rainfall intensity.	+5%	+10%	+20%	+30%
Peak river flow.	+10%	+20%		

9. Highways Agency, (1992), *Design Manual for Roads and Bridges for trunk roads.*

10. National Sustainable Drainage Systems (SuDS) Working Group (2009). *SuDS Interim Code of Practice.*

11. CIRIA Report C689 (2010). *Culvert Design and Operation Guide.*

3.2.5 There is one departure to this; a 30% increase in flow in ungauged catchments has been used in order to account for uncertainty in flow calculations. This approach has been applied only when assessing culverts on small watercourses where no hydraulic modelling has been undertaken.

Freeboard at bridges

3.2.6 A minimum of 600mm freeboard above the 1% AEP+CC flood event has been allowed to the soffit of all bridges and viaducts. On main rivers, where possible, a freeboard of 1000mm has been allowed.

Freeboard at culverts

3.2.7 The freeboard provided between the 1% AEP+CC water level and the soffit of any proposed culvert is a minimum of 300mm for ordinary watercourses and 600mm for main rivers. The exception to this is where new structures are sized to match existing.

Flood protection to the Proposed Scheme rail infrastructure

3.2.8 The Proposed Scheme rail infrastructure (including the track drainage systems) will be designed to be protected against inundation in the 0.1% AEP flood event for both river and surface water flooding. This will be achieved through ensuring either a of 1m between the rail level and the 0.1% AEP flood level, or by providing flood protection with a freeboard of at least 300mm above the 0.1% AEP flood level.

Attenuation of surface run-off

3.2.9 All drainage will be attenuated in order that peak surface run off from the Proposed Scheme in the events up to the 1% AEP+CC peak rainfall event is no greater than the existing current day baseline run-off under the same peak rainfall event.

4 Data sources

4.1.1 The following data sources have been referred to in the compilation of this document:

- Environment Agency web site; http://www.environment-agency.gov.uk/;
- reservoir flood mapping[12];
- generalised river flood mapping and flood zone mapping[13];
- Solihull Metropolitan Borough Council (SMBC) Level 1 Strategic Flood Risk Assessment (SFRA)[14];
- SMBC Preliminary Flood Risk Assessment (PFRA)[15];
- historic flooding records[16];
- flood map for surface water (FMfSW)[17];
- topographic survey (200mm grid resolution laser interferometry detection and ranging (LiDAR) survey, in digital terrain model and digital surface model format) and associated aerial photography;
- as built and historic drawings and land drainage records from Network Rail (NR), BCC & others;
- evidence gathered from site visits (including photographs);
- online photographic & mapping resources (Google maps, Bing maps etc);
- Ordnance Survey 1: 10,000; 1:25,000 and 1:50,000 mapping;
- publicly available planning applications from recent developments within the area of interest;
- sewer network data from Severn Trent Water Plc (STW)[18];
- British Geological Survey (BGS) mapping;
- geotechnical desk studies; and
- Powell et al (2000)[19]: Geology of the Birmingham area.

12.Environment Agency, (2012), *Lakes and reservoirs GIS layer.*

13.Environment Agency, (2012), Flo*od zone mapping GIS layer.*

14.Halcrow, (2008). *Solihull Metropolitan Borough Council (SMBC) Level 1 Strategic Flood Risk Assessment.*

15.WSP, (2011), *Solihull Metropolitan Borough Council Preliminary Flood Risk Assessment.*

16.Environment Agency, (2012), *Midlands Historical 1992 and 2007 flood event GIS layers.*

17.Environment Agency, (2012), *Midlands Flood Map for Surface water GIS layers.*

18.Severn Trent Water, (2012), *Utilities GIS Data.*

19. Powell, JH, Glover, BW, and Waters, CN., (2000),. *Geology of the Birmingham area.* Memoir of the British Geological Survey, Sheet 168 (England and Wales).

5 The proposed development

5.1.1 The route of the Proposed Scheme through the Balsall Common and Hampton-in-Arden area will be approximately 7.8km in length, commencing north-west of Waste Lane (see Volume 2: Map CT-06-100, E6), adjacent to the Kenilworth Greenway and then proceeding towards the existing Rugby to Birmingham line, crossing it south-east of Berkswell station.

5.1.2 Continuing north-east of Berkswell station the route will cross Truggist Lane, Bayleys Brook, Lavender Hall Lane and several public rights of way including the Millennium Way and the Heart of England Way (Footpath M214).

5.1.3 The route will then continue broadly parallel to the A452 Kenilworth Road which it will cross in close proximity to Marsh Lane Nature Reserve. It will then cross over the B4102 Meriden Road, the River Blythe and Diddington Lane and leave this area south-east of the A45 Coventry Road, near to Pasture Farm.

5.2 Design elements

5.2.1 To facilitate the Proposed Scheme the following design elements are required:

- high speed rail lines;
- overhead electrification gantries;
- signals;
- sections of route and side road diversions on embankment;
- sections of route and side road diversions in cutting;
- viaducts and overbridges spanning urban areas, rural land, highways, railways, watercourses and canals;
- bridges under existing urban areas, rail and highway infrastructure;
- flood relief culverts;
- culverts for existing watercourses;
- river diversions; and
- drainage infrastructure.

5.2.2 Within CFA23 the following elements have direct relevance to the assessment of flood risk:

- culvert crossing from Beechwood Farm;
- Balsall Common viaduct over Bayleys Brook;
- diverted Lavender Hall Lane Culvert crossing of Bayleys Brook;
- Marsh Farm viaduct crossing Bayleys Brook;
- bridleway M218 diversion crossing of Bayleys Brook;
- A452 Kenilworth Road diversion crossing of Bayleys Brook ;
- culvert crossing of River Blythe tributary;
- A452 Kenilworth Road culvert crossing of Horn Brook adjacent to Marsh Lane;

- River Blythe viaduct;
- Shadow Brook underbridge; and
- surface water drainage.

6 Existing flood risk

6.1 River flood risk

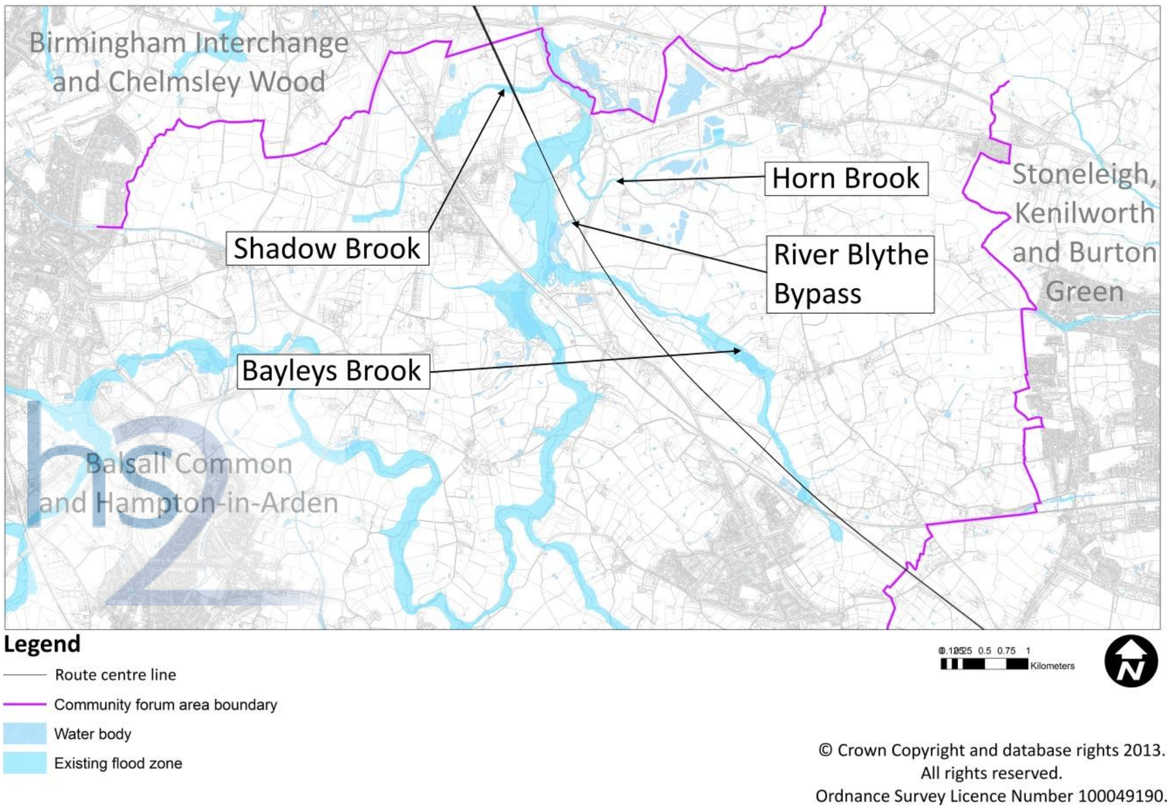
6.1.1 River flood risk is the risk of flooding posed by rivers and streams. The river flood risk within CFA23 is dictated by the risk posed by the River Blythe and its tributaries; Shadow Brook, Bayleys Brook, Horn Brook and smaller un-named tributaries.

River Blythe catchment

6.1.2 The River Blythe is a major tributary of the River Tame and drains parts of North Warwickshire, Solihull and the surrounding rural areas. It has a total catchment of 131km^2 (as taken from the Flood Estimation Handbook (FEH) CD Rom[20]) upstream of the proposed route crossing. It is a Main River and as such is operated and maintained by the Environment Agency. The river reach in proximity to the Proposed Scheme is designated as a Site of Special Scientific Interest (SSSI).

6.1.3 In order to establish the existing flood risk posed by the River Blythe to the land located along and adjacent to the Proposed Scheme reference has initially been made to the existing Flood Zone mapping available from the Environment Agency and shown in Figure 2.

Figure 2: Existing Flood Zone Mapping for the River Blythe and Tributaries (Environment Agency 2012)



20. Centre for Ecology and Hydrology, 1999, *Flood Estimation Handbook (FEH)*

6.1.4 The flood zone mapping indicates that a section of the route and associated infrastructure may be at high risk from inundation from the River Blythe and its tributaries, being partly located in Flood Zone 3a. This indicates that it is at high risk from inundation (during a flood event with a 1% AEP).

6.1.5 In order to fully understand the existing risk posed by the river catchment and to be able to evaluate the impact of the Proposed Scheme on the hydraulic behaviour of the Blythe Catchment, a number of discrete hydraulic models have been created using either fully two dimensional models or one dimensional steady state models. The Environment Agency does not have an existing model of the Blythe catchment.

6.1.6 Hydraulic models were created for each watercourse crossing where the 1% AEP+ 20% CC exceeded $3m^3/s$. Simplified culvert calculations based on C689 were used to assess the post development flood risk impact of smaller watercourses.

6.1.7 The details of the activities undertaken to produce baseline hydraulic models are documented in the modelling reports in Volume 5: Appendix WR-004-017 and WR-004-018, with the hydrological assessment detailed in Volume 5: Appendix WR-004-016.

6.1.8 The hydraulic models have been used to determine baseline water levels along the sections of river channel and on the floodplain for the following flood events:

- 50%;
- 10%;
- 5%;
- 2%;
- 1%;
- 1% + 20% CC;
- 1% + 30% CC (in culverts); and
- 0.1% AEP.

6.1.9 The proposed crossings in the River Blythe catchment are described in the following chapters along with the flood extents and levels derived from the baseline models.

River Blythe

6.1.10 The proposed route crosses the River Blythe to the north of the B4102 Meriden Road and west of the A452 Kenilworth Road.

6.1.11 A preliminary hydrological investigation of the River Blythe has been undertaken in order to understand the magnitude of flows generated by the catchment up to a point a short distance downstream the proposed route crossing point. The hydrology report is included in Volume 5: Appendix WR-004-016.

6.1.12 Due to the watercourse's specific out-of-bank flow patterns a fully two dimensional TUFLOW model has been constructed to assess peak water levels and flood flow paths for a range of flood events for both the baseline and post development scenarios. The details of the model build are discussed in the modelling report included in Volume 5: Appendix WR-004-017.

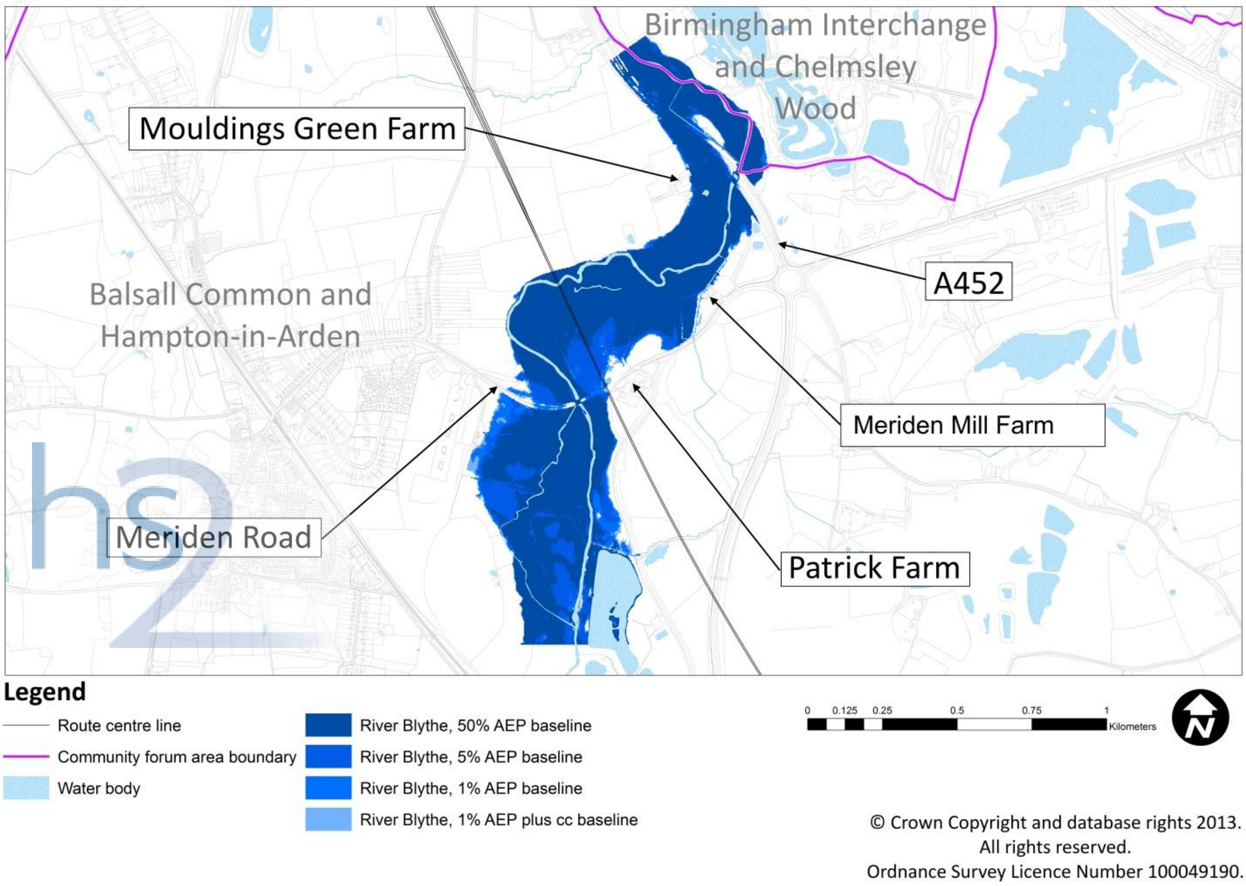
6.1.13 The flows taken forward to the hydraulic analysis are shown in Table 3 below.

Table 3: River Blythe peak flood calculations using the revitalised flood hydrograph (ReFH)[21] method

AEP	Flow (m^3/s)
50%	23.74
10%	34.77
5%	39.21
2%	46.2
1%	52.66
1% plus CC	63.19
0.1%	86.07

6.1.14 The flooding extents for the 1% AEP plus CC generated by the baseline model are shown in Volume 5: Map book WR-05. Figure 3 shows in more detail the baseline flood extents for key return periods.

Figure 3: Flooding extents for the River Blythe from baseline modelling



21. Kjeldsen, T.R., (2007), Supplementary Report N. 1, *The revitalised FSR/FEH rainfall-runoff method*, Centre for Ecology & Hydrology.

6.1.15 The results of the baseline modelling indicate that the location of the route is affected by river flood risk.

6.1.16 The flood extents predicted by the baseline model provide indicative definition of the floodplain, particularly at B4102 Meriden Road. The B4102 Meriden Road is a minor road which provides a link from Hampton-in-Arden to the A452 Kenilworth Road. The hydraulic modelling indicates that B4102 Meriden Road is overtopped in the baseline case. This is event from events in excess of the 10% AEO event. At the 10% AEP event, there is a limited amount of flooding to the east of the existing Meriden Road bridge. The model does not show overtopping of the bridge under events up to the 1% AEP plus CC due to the topography of the bridge's road deck.

6.1.17 Other flood receptors in the vicinity of the route include Patrick Farm, Meriden Mill Farm and Mouldings Green Farm all located on the east side of the River Blythe viaduct. Both floodplains of the River Blythe in this area are occupied by agricultural land. The eastern side of Hampton-in-Arden is located west (upstream) of the River Blythe viaduct. The A452 crosses the River Blythe downstream of the proposed route crossing.

6.1.18 Meriden Mill Farm and Mouldings Green Farm are within the modelled extents of the 50% AEP floodplain. Patrick Farm is outside of the modelled flood extents. The 1% AEP+ CC does not extend into Hampton-in-Arden. The A542 Kenilworth Road is predicted to flood for a 5% AEP.

Shadow Brook

6.1.19 Shadow Brook is a tributary of the River Blythe and is a Main River. The Brook flows in a north-easterly direction to the north of Hampton-in-Arden, joining the River Blythe immediately to the east of the A452 Kenilworth Road. The catchment area is approximately 4.3km^2 and is semi-rural in nature.

6.1.20 The route crosses Shadow Brook over Diddington Lane. At this location, there is an existing culvert which conveys Shadow Brook beneath Diddington Lane.

6.1.21 Due to the watercourse's relatively linear, uniform floodplain at the proposed route location a 1D steady state model (HEC-RAS) of Shadow Brook was considered sufficient for assessing peak water levels for the range of flood events for both the baseline and post development scenarios. The details of the model build are discussed in the modelling report included Volume 5: Appendix WR-004-018.

6.1.22 A preliminary hydrological investigation has been undertaken in order to understand the magnitude of flows generated by the catchment up to a point a short distance downstream the proposed route crossing point. The hydrology report is included in the appendices. The flows taken forward to the hydraulic analysis are shown in Table 4.

Table 4: Shadow Brook peak flow calculation results using ReFH

AEP	Flow (m^3/s)
50%	1.46
20%	1.93
10%	2.31
5%	2.69
2%	3.29
1%	3.83
1% AEP+20%	4.59
0.1%	6.86

6.1.23 The flooding extents for a selection of flood events up to the 1% AEP+ CC event generated by the baseline model are shown on in Figure 4. The flood extents generated by the 5% and 1% plus CC AEP are shown in full in the Volume 5: Map Book WR-05 and WR-06. Water levels at key locations for the full range of return periods are provided in Table 5.

Figure 4: Flooding extents for the 1% AEP plus 20% CC for Shadow Brook from baseline modelling

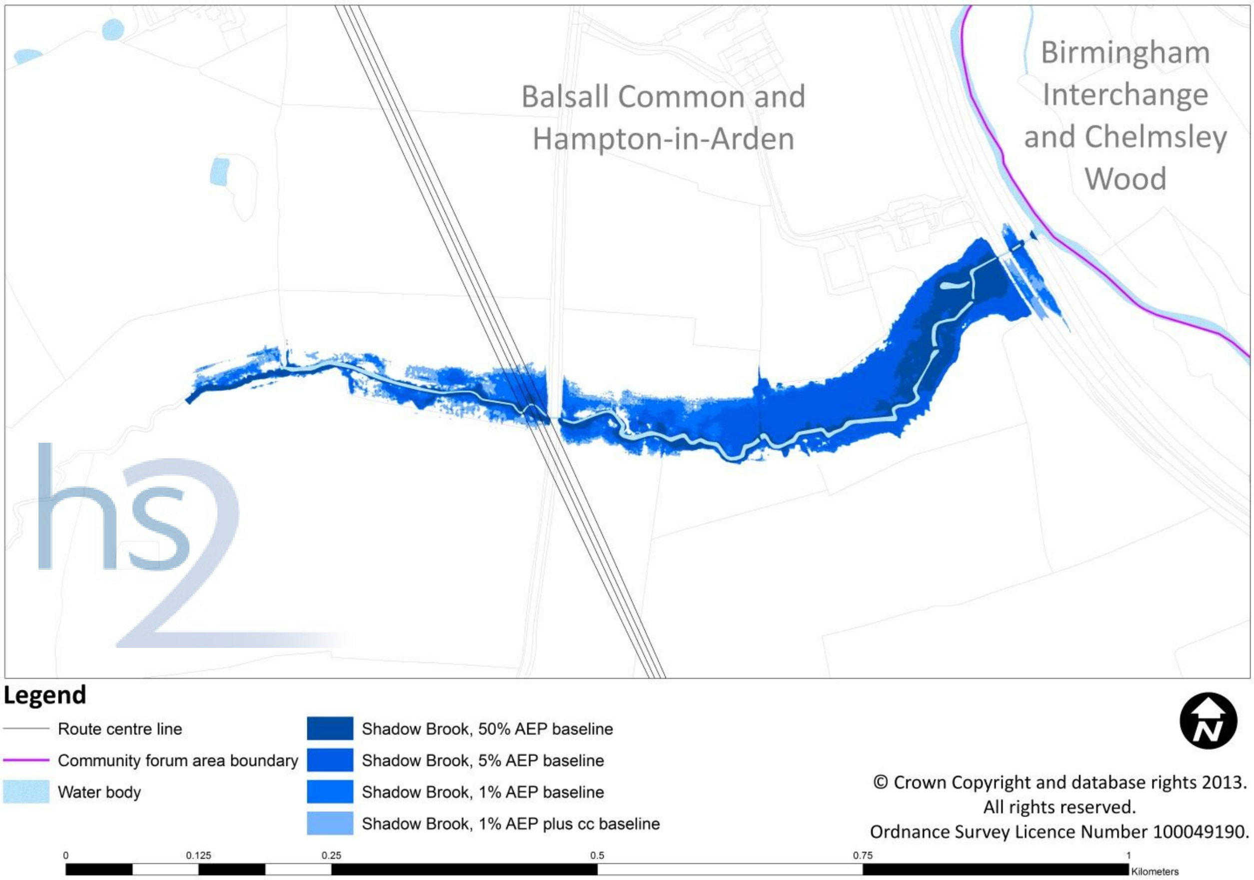


Table 5: Shadow Brook flood levels (mAOD) (for cross-section locations see Volume 5: Appendix WR-004-018 Section 3)

	AEP					
Proposed Scheme Feature	**50%**	**10%**	**5%**	**2%**	**1%**	**1% plus CC**
Downstream of Shadow Brook underbridge, cross-section 626	84.853	84.997	85.059	85.141	85.213	85.312
Upstream of Shadow Brook underbridge, cross-section 713	84.96	85.114	85.176	85.259	85.326	85.413
150m Upstream of Shadow Brook underbridge, cross-section 859	85.285	85.458	85.499	85.563	85.615	85.682

6.1.24 The results of the baseline modelling confirm that the location of the route is affected by river flood risk.

6.1.25 The flooding extents from the baseline model are broadly consistent in shape with the Environment Agency flood zone mapping data but the modelled flood extents are considerably narrower in the upstream reach and offset from the Environment Agency's flood zone mapping due to inconsistencies with the simplified terrain data used to derive the mapping.

6.1.26 The key flood receptors in the vicinity of the development are agricultural land located both upstream and downstream of the existing Diddington Lane crossing, a wooded area located on the left bank and Diddington Hall which is elevated above the floodplain on the left bank of the watercourse. While Diddington Hall itself is outside of the floodplain the access to the hall is only marginally above the 1% AEP plus CC flood level.

6.1.27 The A452 Kenilworth Road may be at risk of overtopping during extreme flood events; however, the levels predicted by the model are based on assumed culvert dimensions. Further survey information on the A452 Kenilworth Road culvert in the vicinity of Diddington Farm would be required to accurately assess the over topping risk.

Bayleys Brook at Balsall Common viaduct

6.1.28 Bayleys Brook is a tributary of the River Blythe and is an Ordinary Watercourse for which Solihull Metropolitan Borough Council (SMBC) are the Lead Local Flood Authority. The brook originates to the east of Balsall Common and flows in a north-westerly direction, where it flows parallel to the A452 Kenilworth Road. The brook confluences with the River Blythe to the south east of Hampton-in-Arden, approximately 200m after crossing the A452 Kenilworth Road and Marsh Lane. The catchment area is approximately 11.3km^2 and is predominantly rural, with small urban contributions from Balsall Common and Berkswell. The brook bisects a Site of Special Scientific Interest (SSSI) (Berkswell Marsh) along its route.

6.1.29 The proposed route runs parallel to Bayleys Brook and crosses the brook in two separate locations at Marsh Farm and Balsall Common. There will be two further crossings of Bayleys Brook for a diversion of the A452 Kenilworth Road at Marsh Farm and at Lavender Hall Lane.

6.1.30 Due to the skew angle of the Balsall Common viaduct a fully two dimensional model of Bayleys Brook has been constructed using TUFLOW to assess peak water levels and flood flow paths for a range of flood events for both the baseline and post development scenarios. The details of the model build are discussed in Volume 5: Appendix WR-004-017.

6.1.31 A preliminary hydrological investigation has been undertaken of Bayleys Brook in order to understand the magnitude of flows generated by the catchment up to a point a short distance downstream the proposed route crossing point. The hydrology report is included in Volume 5; Appendix WR-004-016.

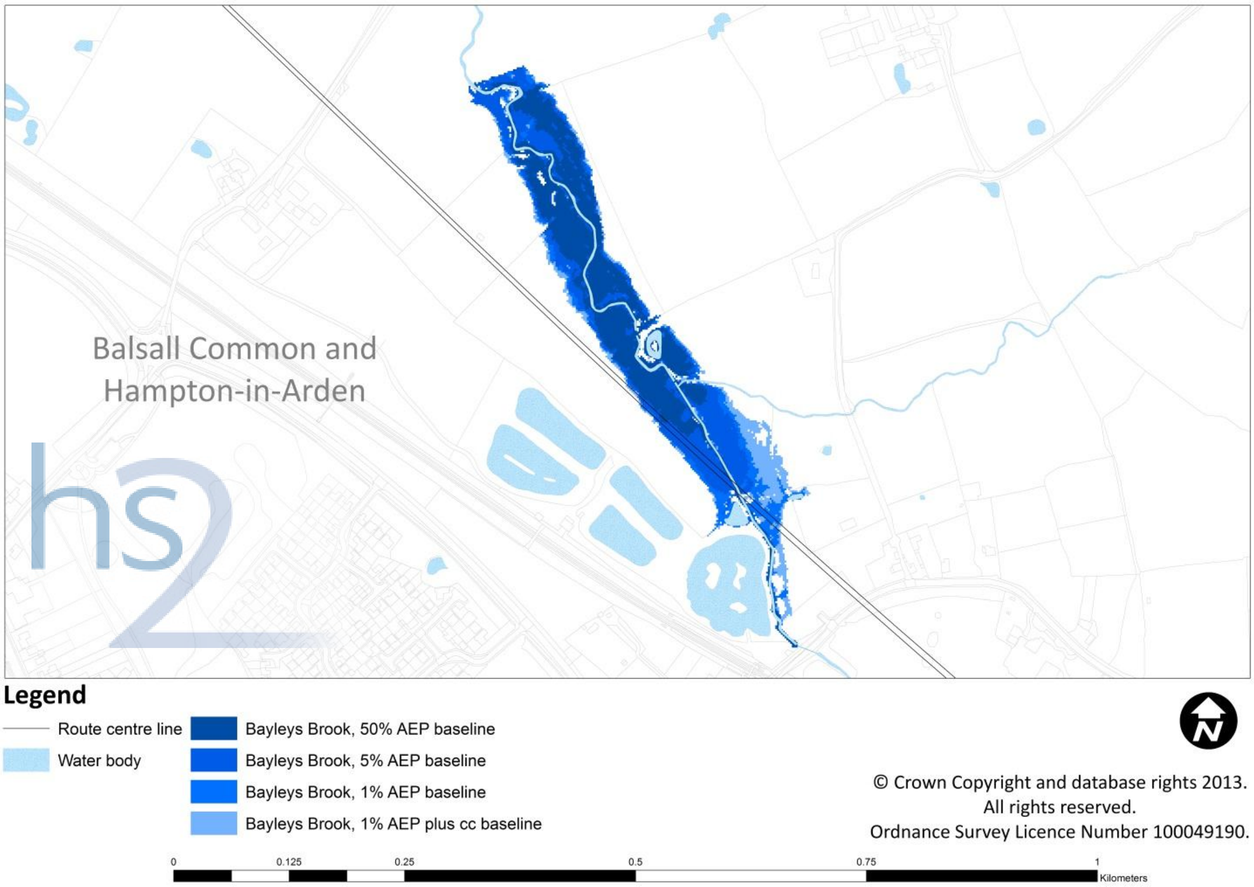
6.1.32 The flows taken forward to the hydraulic analysis are shown in Table 6 below.

Table 6: Bayleys Brook peak flow calculation results using ReFH

AEP	**Flow (m^3/s)**
50%	1.64
20%	2.16
10%	2.56
5%	2.98
2%	3.62
1%	4.20
1% AEP + CC	5.04
0.1%	7.46

6.1.33 The flooding extents for a range of return periods up to the 1% AEP + CC generated by the baseline models are shown on in Figure 5. The flood extents are provided in Volume 5: Map book WR-05 and WR-06 for the 1% AEP plus CC and the 5% AEP events.

Figure 5: Flooding extents for the 1% AEP + 20% CC for Bayleys Brook from baseline modelling



6.1.34 The results of the baseline modelling indicate that the location of the proposed route is affected by river flood risk.

6.1.35 The flooding extents from the baseline model are broadly consistent with the Environment Agency's flood zone mapping. The notable exception is the lack of flooding within the pond to the west, and a smaller extent to the east of Bayleys Brook. This is due to the differences in the quality of digital terrain models used; where the Environment Agency's flood zone mapping data did not include the embankments surrounding the pond area.

6.1.36 Key flood risk receptors are the upstream Truggist Lane, agricultural land, Lavender Hall Farm and fisheries located on the western bank of the watercourse. The fisheries are shown to be outside of the 1% AEP + CC flood extent as they are bounded by a high ridge on their eastern boundary. The fisheries could still be susceptible to inundation from flood water through any outfalls discharging into Bayleys Brook.

6.1.37 The model extent does not reach upstream to Truggist Lane and the baseline flood risk to this receptor is not directly assessed. Any backwater affect from the proposed development and resultant increase in flood risk is discussed in the post development section of this report.

6.1.38 It is noted from the Environment Agency flood mapping that Truggist Lane may suffer from flooding and there is a low spot in vertical alignment of the highway as it passes beneath the rail line. Interrogation of the topography at and upstream of the road crossing would support the likelihood that any overtopping of Truggist Lane would most likely flow towards the low point of the road. Berkswell Station is located off Truggist Lane to the south west of the proposed development. The railway line itself is demonstrated to be outside of the 1% AEP floodplain extent for the model extents. The railway may be at risk of flooding upstream of Truggist Lane.

Bayleys Brook at Marsh Farm crossing

6.1.39 A one dimensional steady state model (HEC-RAS) was considered sufficient for assessing peak water levels for the range of flood events for both the baseline and post development scenarios for this crossing. The details of the model build are discussed in the modelling report included Volume 5: Appendix WR-004-018.

6.1.40 A preliminary hydrological investigation has been undertaken in order to understand the magnitude of flows generated by the catchment up to a point a short distance downstream of the proposed route crossing point. The hydrology report is included in Volume 5: Appendix WR-004-016.

6.1.41 The flows taken forward for hydraulic analysis are shown in Table 7 below.

Table 7: Bayleys Brook (Marsh Farm) peak flow calculation results using ReFH

AEP	Flow (m^3/s)
50%	2.27
20%	2.94
10%	3.46
5%	3.99
2%	4.82
1%	5.56
1% AEP+ CC	6.67
0.1%	9.73

6.1.42 The flooding extents for a range of return periods up to the 1% AEP + CC generated by the baseline models are shown on in Figure 6. The flood extents are provided in Volume 5: Map book WR-05 and WR-06 for the 1% AEP plus CC and the 5% AEP events. While water levels at key locations for the full range of return periods are provided in Table 8.

Figure 6: Flooding extents for the 1% AEP plus CC for Bayleys Brook from baseline modelling

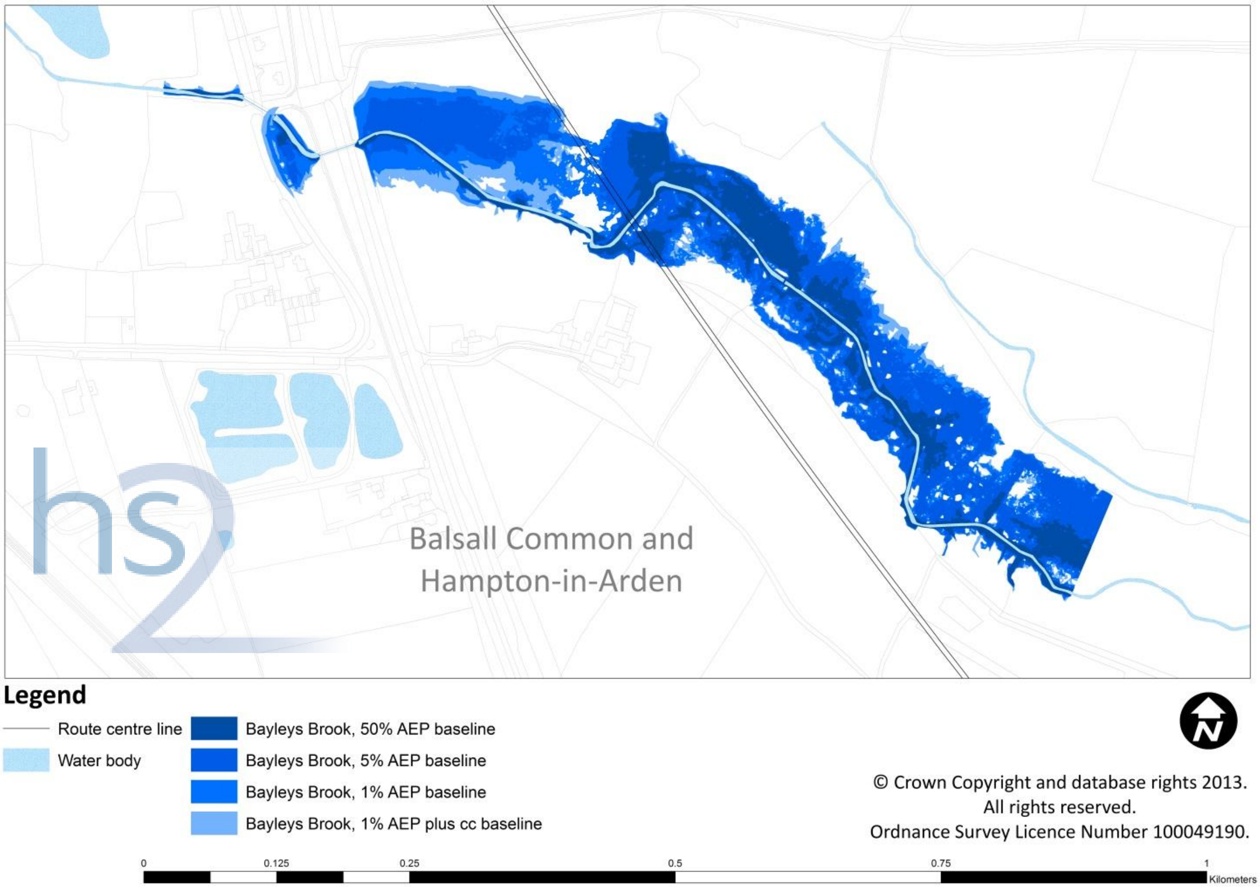


Table 8: Bayleys Brook flood levels (mAOD) at Marsh Farm (for cross-section locations see Volume 5: Appendix WR-004-018 Section 6)

	AEP					
Proposed Scheme Feature	**50%**	**10%**	**5%**	**2%**	**1%**	**1% plus CC**
Upstream of Marsh Lane, model cross-section 6	88.804	88.935	89.026	89.112	89.377	89.534
A452 & Bridleway Diversion – upstream of A452, model cross-section 8	89.605	89.672	89.704	89.707	89.741	89.843
Upstream, model cross-section 8.4	90.521	90.594	90.645	90.676	90.71	90.734
Upstream, model cross-section 11	90.788	90.842	90.875	90.903	90.938	90.968
Parallel to route – Baseline, model cross-section 12	90.996	91.035	91.061	91.086	91.12	91.151

6.1.43 Key flood risk receptors associated with Marsh Farm are Mercote Lodge and Marsh Farm Cottage which are located upstream of the A452 Kenilworth Road, both are elevated above the 1% AEP plus CC floodplain. Berkswell Marsh SSSI is located approximately 500m upstream of the proposed route crossing but is within the baseline floodplain. As such any changes to the hydrological operation of the watercourse could adversely impact on the SSSI. Mercote Lodge is located downstream of Marsh Lane and while it is identified as being outside of the 1% AEP plus CC flood extent it may be at risk of flooding via any drainage outfall connections. It should also be noted that there is uncertainty regarding the flood modelling due to absence of channel survey data.

6.1.44 Following analysis using the one dimensional model the floodplain was noted to split from the channel with divided flow. A two dimensional model may be required for future analysis to improve the accuracy of the modelling results in conjunction with further survey work.

6.1.45 Environment Agency river network GIS data notes a possible culvert from a tributary of the Bayleys Brook to the River Blythe Bypass Channel, this is shown on Volume 5: Map WR-01-040. The culvert is denoted as assumed in the Environment Agency data and the presence of this culvert is currently unconfirmed. The flows that would pass through this culvert have been included in the flood modelling and assessment for Bayleys Brook at the Marsh Farm viaduct. The existence of this culvert will be confirmed during the detailed design stage and should a diversion be required this will developed in consultation with the Environment Agency and Lead Local Flood Authority.

Lavender Hall Lane

6.1.46 Due to the watercourse's relatively linear, uniform floodplain at the proposed route location a one dimensional steady state model (HEC-RAS) was considered sufficient for assessing peak water levels for the range of flood events for both the baseline and post development scenarios. The details of the model build are discussed in the modelling report included in Volume 5: Appendix WR-004-018.

6.1.47 A preliminary hydrological investigation has been undertaken in order to understand the magnitude of flows generated by the catchment up to a point a short distance downstream of the proposed route crossing point. The hydrology report is included in Volume 5: Appendix WR-004-016.

6.1.48 The flows taken forward to the hydraulic analysis are shown in Table 9 below. Climate change has been included as a 30% increase on the 1% AEP flows as the proposed structure is a culvert.

Table 9: Bayleys Brook peak flow calculation results using ReFH

AEP	Flow (m^3/s)
50%	1.8
20%	2.4
10%	2.8
5%	3.2

AEP	Flow (m^3/s)
2%	3.9
1%	4.6
1% AEP+20%	5.5
1% AEP+30%	5.9
0.1%	8.1

6.1.49 The flooding extents for a range of flood events up to the 1% AEP plus 30% CC generated by the baseline models are shown on in Figure 7. The flood extents for the 5% AEP and 1% AEP plus CC are included in Volume 5: Map Book WR-05 and WR-06. Water levels at key locations for the full range of return periods are provided in Table 10.

Figure 7: Flood extents for the 1% AEP plus 30% CC for Bayleys Brook from baseline modelling

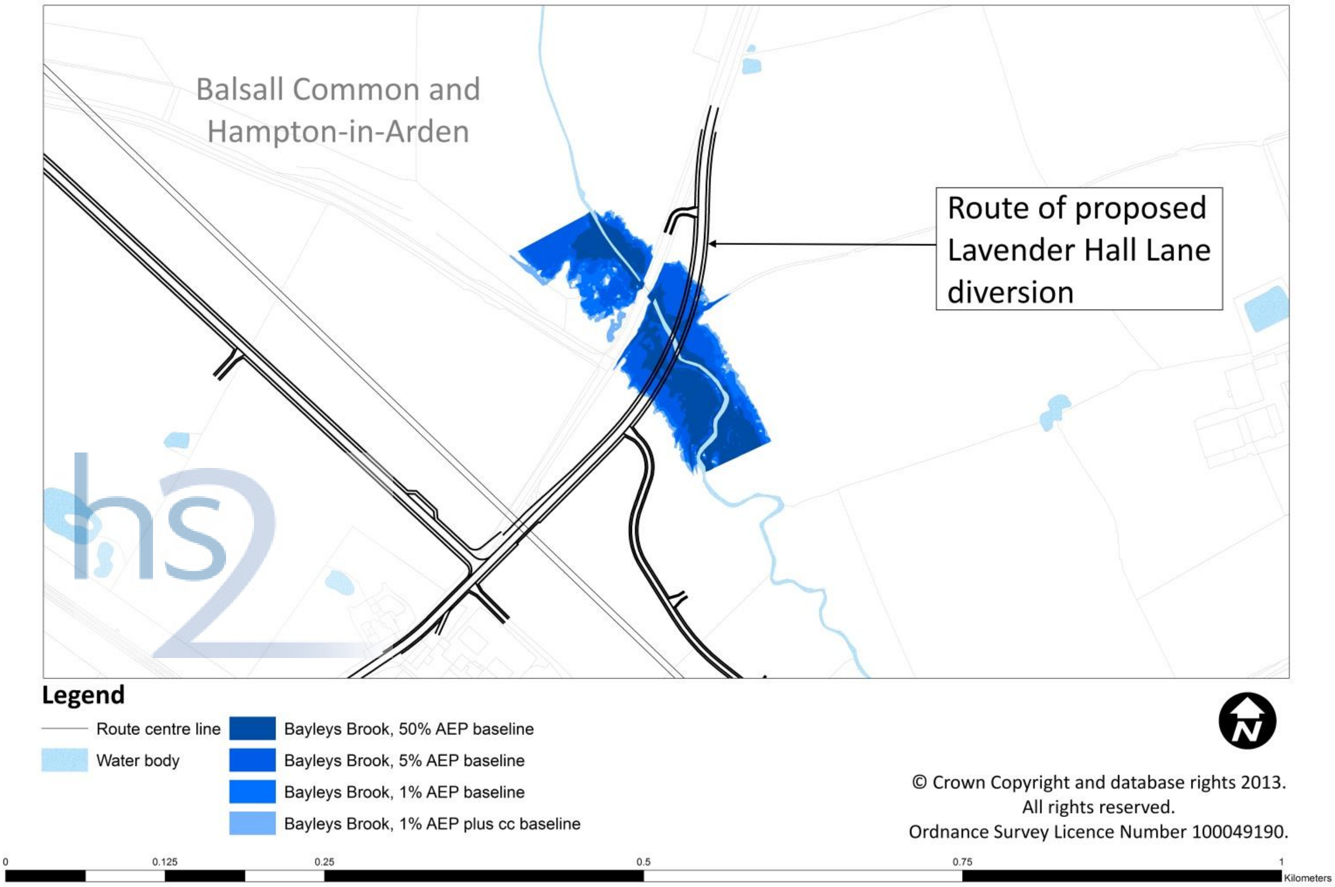


Table 10: Bayleys Brook flood levels (mAOD) at Lavender Hall Lane (for cross-section locations see Volume 5: Appendix WR-004-018 Section 5)

	AEP					
Proposed Scheme Feature	**50%**	**10%**	**5%**	**2%**	**1%**	**1% plus CC**
A452 Diversion downstream of Lavender Hall Lane (model cross-section 4)	102.05	102.198	102.302	102.405	102.412	102.448
Upstream of Lavender Hall Lane diversion (model cross-section 5)	102.445	102.481	102.479	102.517	102.55	102.603

6.1.50 The results of the baseline modelling confirm the extent to which Lavender Hall Lane is currently affected by river flood risk.

6.1.51 The flooding extents from the baseline model are broadly consistent with the flood zone mapping data although the upstream position aligns more accurately with the main channel position.

6.1.52 The existing Lavender Hall Lane is predicted to over top for events exceeding the 10% AEP. Park Lane is also located downstream of the Lavender Hall Lane but is not predicted to flood up to the 1% AEP plus 30% CC. Other receptors in the vicinity of the Lavender Hall Lane crossing are agricultural land located either side of the crossing and Park Lane Spinney located immediately downstream on the left bank.

River Blythe bypass (River Blythe tributary)

6.1.53 The River Blythe bypass is a watercourse that diverges from a larger channel (Horn Brook) which originates to the east of the A452 Kenilworth Road. The divergence occurs immediately downstream of the road crossing with the majority of flow being conveyed by the Horn Brook which flows in a northerly direction towards the River Blythe. The River Blythe bypass is a secondary channel which conveys a smaller proportion of flow in a south-westerly direction while also functioning as a land drain. The hydraulic model splits the flow between the Horn Brook and River Blythe Bypass, with less than 20% of the catchment flow discharging to the Blythe Bypass.

6.1.54 The watercourse confluences with the River Blythe approximately 320m downstream of the route. The catchment area is approximately $11.3km^2$ and is predominantly rural. It is an Ordinary Watercourse for which SMBC are the Local Flood Authority.

6.1.55 Due to the watercourse's relatively linear, uniform floodplain at the proposed route location a one dimensional steady state model (HEC-RAS) was considered sufficient for assessing peak water levels for the range of flood events for both the baseline and post development scenarios. The details of the model build are discussed in the modelling report included in Volume 5: Appendix WR-004-018.

6.1.56 A preliminary hydrological investigation has been undertaken in order to understand the magnitude of flows generated by the catchment up to a point a short distance downstream the proposed route crossing point. The hydrology report is included in the Volume 5: Appendix WR-004-016.

6.1.57 The flows taken forward to the hydraulic analysis are shown in Table 11 below.

Table 11: River Blythe bypass peak flow calculation results using ReFH

AEP	Total Flow (m^3/s)
50%	1.52
20%	1.99
10%	2.36
5%	2.75
2%	3.35
1%	3.90
1% AEP+20%	4.68
0.1%	7.05

6.1.58 The flooding extents for a range of return periods up to the 1% AEP + CC generated by the baseline models are shown on in Figure 8. The flood extents are provided in Volume 5: Map book WR-05 and WR-06 for the 1% AEP plus CC and the 5% AEP events. While water levels at key locations for the full range of return periods are provided in Table 12.

Figure 8: Flooding extents for the 1% AEP plus 20% CC for River Blythe Bypass from baseline modelling

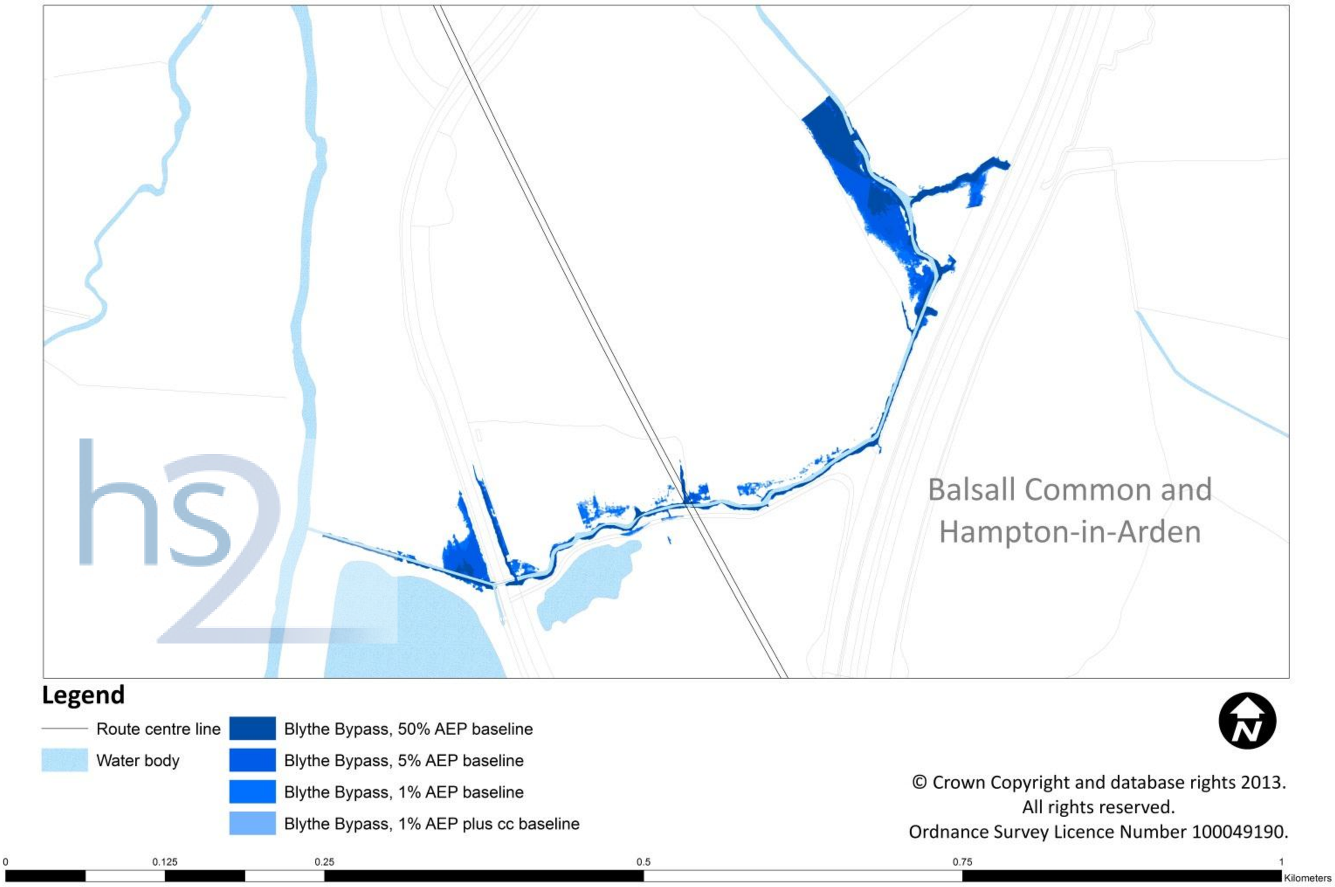


Table 12: River Blythe Bypass flood levels (m) at Blythe Bypass culvert (for cross-section locations see Volume 5: Appendix WR-004-018 Section 7)

	AEP					
Proposed scheme feature	**50%**	**10%**	**5%**	**2%**	**1%**	**1%plus CC**
Downstream of River Blythe Bypass culvert, model cross-section 311	86.161	86.229	86.269	86.355	86.39	86.423
Downstream of River Blythe Bypass culvert, model cross-section 355	86.222	86.327	86.376	86.407	86.438	86.471

6.1.59 The results of the baseline modelling confirm the extent to which the route is affected by river flood risk.

6.1.60 The flooding extents from the baseline model are generally consistent with the Environment Agency flood zone mapping data at the proposed route crossing, showing a significant backwater extent from the River Blythe extending beyond the River Blythe bypass culvert.

6.1.61 Flood risk receptors are primarily agricultural land although the A452 Kenilworth Road is crosses the Blythe Bypass channel upstream of the Proposed Scheme and will be diverted as part of the Proposed Scheme.

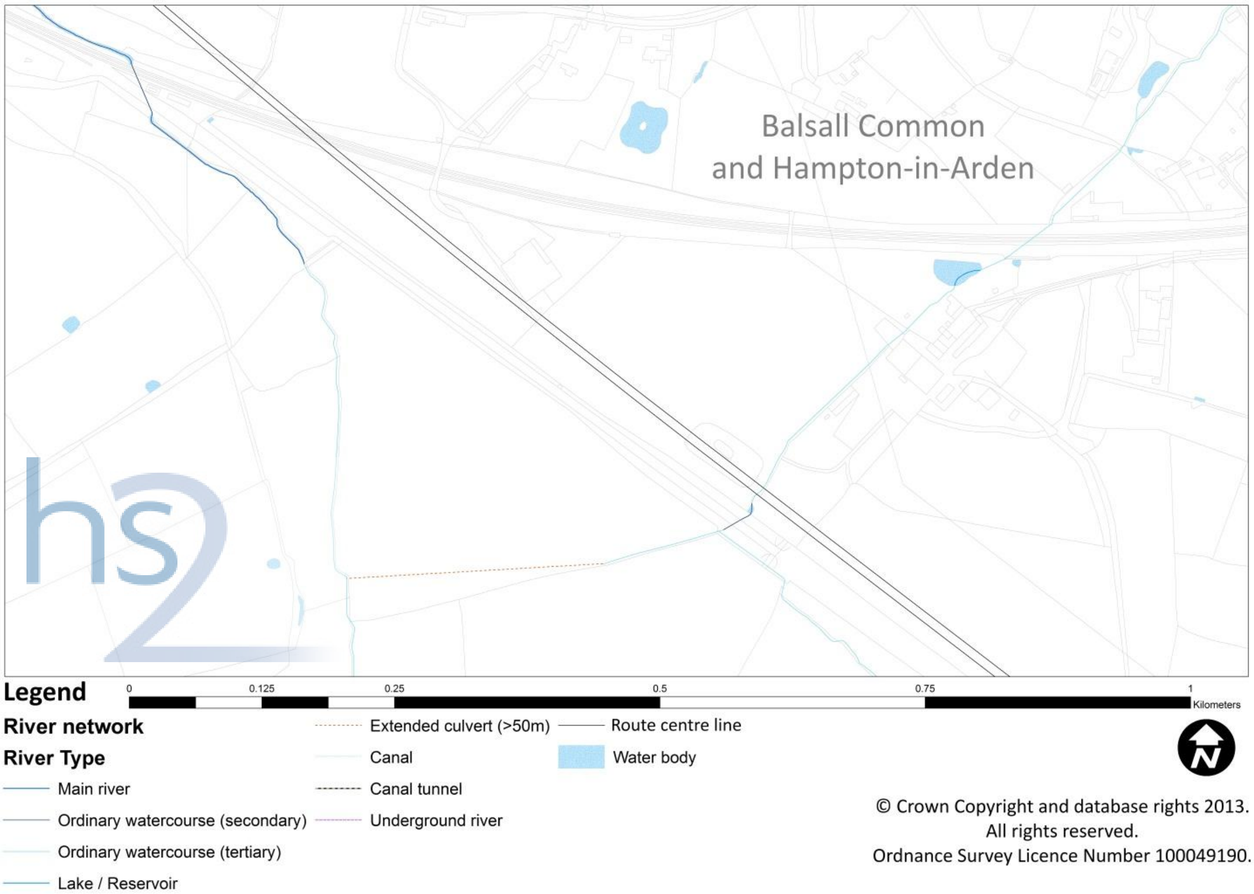
Other tributaries

6.1.62 There is one minor watercourse that also crosses the proposed route north-west of Beechwood Farm underpass. The location of this watercourse is shown in Figure 9.

6.1.63 There is an un-named watercourse that is a small tributary of Bayleys Brook and drains a predominantly rural catchment of 2.9km^2. There is an existing culvert located downstream of the Proposed Scheme which passes beneath an abandoned railway embankment (now part of the Kenilworth Greenway). There is no floodplain identified on the Environment Agency flood zone mapping.

6.1.64 A preliminary hydrological investigation has been undertaken in order to understand the magnitude of flows generated by the catchment up to a point a short distance downstream the proposed route crossing point. The hydrology report is included in Volume 5: Appendix WR-004-016.

Figure 9: Watercourse crossing at Beechwood Farm



6.1.65 The flows taken forward to the hydraulic analysis are shown in Table 13.

Table 13: Peak flow calculation results using ReFH

AEP	Peak flow (m^3/s)
50%	0.9
20%	1.18
10%	1.40
5%	1.63
2%	1.98
1%	2.30
1% AEP+20%	2.76
1% AEP+30%	2.99
0.1%	4.10

6.1.66 Detailed baseline flood mapping has not been established for this smaller watercourse but the potential impact of the development on flood risk and the risk to the development has been assessed using the culvert analysis method described in CIRIA Report C689. The flood risk management of these smaller watercourses is discussed in Section 8.

6.2 Surface water flooding

6.2.1 This section is an examination of the existing flood risk posed by rainfall hitting the ground surface. This is often referred to as surface water. In this section it is examined in two ways (i) in terms of the risk posed in the event of failure or exceedance of existing drainage systems, and (ii) in terms of examining the pathways exploited by water flowing over the ground.

6.2.2 This can manifest itself as ponding or surface water flow when flows cannot enter a drainage system because the capacity is exceeded. Flooding can also occur when the surface water flow pathway reaches a receptor. This is also referred to as surface water flood risk.

6.2.3 Flood risk is assessed by examining existing surface water flow routes and reviewing the potential risk posed by the existing systems in place designed to manage surface water.

Drainage systems

6.2.4 The proposed route commences north-west of Waste Lane (see Volume 2: Map CT-06-100, E6), adjacent to the Kenilworth Greenway and then proceeding towards the existing Rugby to Birmingham line, crossing it south-east of Berkswell station.

6.2.5 Continuing north-east of Berkswell station the route will cross Truggist Lane, Bayleys Brook, Lavender Hall Lane and several PRoW including the Millennium Way and the Heart of England Way (Footpath M214).

6.2.6 The route will then continue broadly parallel to the A452 Kenilworth Road which it will cross in close proximity to Marsh Lane Nature Reserve. It will then cross over the B4102 Meriden Road, the River Blythe and Diddington Lane and leave this area south-east of the A45 Coventry Road, near to Pasture Farm.

6.2.7 Due to the semi-rural location, there are only localised sewer networks through this area. The majority of the drainage systems will be the responsibility of Severn Trent Water and SMBC for highway drainage.

Route wide within CFA23

6.2.8 The existing public sewer networks owned by Severn Trent Water within the catchments affected have been interrogated and there are no significant interactions between the Proposed Scheme and the existing sewerage network within the Balsall Common and Hampton-in-Arden area. Highway drainage and some private drainage may be encountered along the route but no records are available to inform this flood risk assessment.

Surface water flow flood risk

6.2.9 The assessment of the existing flood risk posed by existing surface water flow routes has been based on the following:

- an investigation of existing topography using contours generated from LiDAR survey data;
- examining the Environment Agency's surface water flood mapping; and
- documenting any reported instances of flooding from the SMBC's SFRA and PFRA.

6.2.10 The proposed route crosses a number of natural drainage paths which form valleys in the topography. Consequently local surface water routes are towards the proposed route in number of localities. The general direction of surface water flow is shown in Annex A. These plans do not take into account the influence of infrastructure such as roads where any surface water flow could be intercepted by artificial drainage.

6.2.11 The Environment Agency's surface water flood mapping has also been examined and is shown in drawing series Volume 5: Map Book WR-01-039 and WR-01-040. These have been compiled by the Environment Agency using a simple ground model to indicate where surface water would be expected to flow or pond during the 0.5% AEP rainfall event. The mapping provides an indication of flooding greater than 0.1m depth and flooding greater than 0.3m deep. This data does have limitations but illustrates areas that may be at risk and where a more detailed study may be required as the design develops.

6.2.12 The data set primarily identifies flooding along watercourse floodplains which is addressed separately as part of this flood risk assessment. However, there are a number of significant features that would be expected to accumulate significant depths of water during rainfall events. The data set has been used to identify the following locations along or in close proximity of the propose route where surface water flow may be a flood risk consideration:

- ponding to the north east of Kenilworth Greenway (elevated on embankment;
- ponding adjacent to the existing railway embankment west of Carol Green;
- ponding of surface water at a low point in topography formed by the embanked A452 Kenilworth Road; and
- ponding of water behind the embanked A45 Coventry Road (south of Birmingham interchange station).

6.2.13 The PFRA reports a single historic flood event within 500m of the proposed route, located to the east of Berkswell Station, approximately 50m from the route. Surface water drainage will be designed for the scheme, and provided all mitigations measures identified are included there is no significant increase in flood risk identified.

6.3 Groundwater

6.3.1 Groundwater flood risk within the Balsall Common and Hampton-in-Arden area has been qualitatively assessed based on hazard identification and evaluation using the conceptual understanding of the ground conditions along the route as informed by geotechnical desk studies. The assessment of baseline groundwater flood risk is based on the presence or otherwise of an aquifer and the relative depth to groundwater level, as well as historical information on the occurrence of groundwater flooding incidents.

Baseline description

6.3.2 The following sections present details of the ground conditions along the route within the Balsall Common and Hampton-in-Arden area and a literature review of historical groundwater flooding incidents from the SMBC SFRAs.

Geology

6.3.3 The solid and superficial geology of the route corridor is presented below.

Solid geology

6.3.4 The geological structure of the Balsall Common and Hampton-in-Arden area comprises Triassic deposits (Mercia Mudstone group) forming part of the Knowle Basin, overlain by glacial and alluvial superficial deposits. At Lavender Hall Lane overbridge the route will cross the Meriden fault, which trends north to south and forms the western margin of the Warwickshire coalfield. South-east of this location, the geological structure comprises the uppermost part of the carboniferous Warwickshire group (Tile Hill Mudstone formation) overlain by alluvial superficial deposits. At depth the productive coal measures which include the Warwickshire thick coal are present.

6.3.5 Carboniferous Tile Hill Mudstone is present beneath the route in the Balsall Common and Hampton-in-Arden area from the start of the section at Burton Green to the western boundary fault at about Lavender Hall Lane. North-west of this fault the bedrock geology is the Triassic Mercia Mudstone Group for the remainder of the section. Near the Marsh Farm viaduct, a fault associated with an outcrop of Bromsgrove Sandstone just to the east intersects the proposed route. Around Diddington Lane there is a 150m wide outcrop of Arden Sandstone, which includes beds of sandstone and mudstone.

Superficial geology

6.3.6 In terms of superficial geology, the area of the route within the Balsall Common and Hampton-in-Arden area is characterised by widespread glacial deposits dating from the Mid Pleistocene. These comprise Glaciofluviual deposits, Glaciolacustrine deposits and Glacial Till.

6.3.7 The Glaciofluvial deposits are generally sands and gravels, forming large plateaux. These are locally up to approximately 25m thick and have been quarried in the area. One significant area extends from Lavender Hall Lane to Patrick Farm.

6.3.8 A small outlier of Glaciofluvial deposits is also present from near the Pasture Farm overbridge to near the A45 Coventry Road service road overbridge around Diddington Hill, just south of the A45 Stonebridge Highway.

6.3.9 Glaciolacustrine deposits, typically laminated clays and silts, are only mapped near Birmingham Business Park from the M42 motorway underbridge northward. Whilst this is mostly outside the extents of this area (CFA23), Glaciolacustrine clays were also identified in some historic boreholes as noted in the following sections.

6.3.10 The Glacial Till has been largely eroded but occurs beneath the proposed route between the Heart of England Way bridge and the Sixteen Acre Wood bridge.

6.3.11 A thin covering of Head deposits is present on valley sides and slopes in the area, locally up to several metres thick. This is not shown on the BGS mapping but was identified in a number of the historic boreholes.

6.3.12 Narrow channels of Alluvium are present close to stream courses, overlying the glacial deposits. The River Blythe valley contains more mature river deposits where the route will cross it between the River Blythe overbridge and near the River Blythe viaduct including River Terrace deposits and a wider channel of Alluvium.

6.3.13 Made Ground occurs at various locations throughout the route within this study area. It is mainly associated with highway earthworks and landscaping around developments, but has also been used for land raise and backfill to gravel pits.

6.3.14 Superficial glacial deposits resulting from several phases of glaciations during the Anglian and probably Wolstonian glacial periods, between approximately 400,000 and 200,000 years ago, are present beneath much of the route within the study area. Due to erosion after the last glacial phase, the cover of glacial material is discontinuous in places. During the last (Devensian) glacial period, that finished approximately 10,000 years ago, glacial ice did not reach this area, but periglacial permafrost conditions prevailed across the region.

6.3.15 Most of the glacial deposits beneath the route within the study area are sands and gravels formed during a glacial retreat phase by southward flowing melt water. These glacial sands and gravels form an extensive, but now dissected spread, beneath the axis of the River Blythe valley and form a significant local aggregate resource. They vary widely in lithology from fine grained silty sands to coarse poorly sorted boulder gravel. They are generally 5m-10m thick but can be up to 15m thick.

Hydrogeology

6.3.16 The strata have been classified using the Environment Agency aquifer classification framework[22] which is consistent with The Water Environment (EU Water Framework Directive (2000)[23]) England and Wales) Regulations. (2003). Statutory Instrument 2003 Mo. 3242. The aquifer designations for each stratum are summarised in Table 14.

22. Environment Agency, (2013). *Aquifer Classification Framework* [online], [Accessed 05-02-2013]. Available from: http://www.environment-agency.gov.uk/homeandleisure/117020.aspx.

23. Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy, European Council.

Table 14: Aquifer designations for geological units in CFA23

Geological Unit	Aquifer Designation
Alluvium	Secondary A
Head	Secondary Undifferentiated
River Terrace Deposits	Secondary A
Glacial Till	Unproductive
Glaciofluvial Deposits and Glacioacustrine Deposits	Secondary A
Mercia Mudstone	Secondary B
Arden Sandstone	Secondary A
Bromsgrove Sandstone (Sherwood Sandstone Group)	Principal
Tile Hill Mudstone (Warwickshire Group)	Principal

6.3.17 The Aquifer Designation is as follows:

- Secondary A Aquifers are considered to consist of variable permeability layers capable of supporting water supplies at a local scale.
- Secondary B Aquifers are predominantly of lower permeability and may locally store groundwater due to localised features such as thin fissures, thin permeable horizons and weathering.
- Principal Aquifers are highly inter-granular and/or fractured and the permeability is such that they are able to support water supply and river base flow at a strategic scale.

6.3.18 No Groundwater Source Protection Zones (SPZ) are located along or within 250m of the proposed route as shown on drawing WR-02-23 groundwater baseline.

6.3.19 The valley bottom of a tributary to the River Blythe at the Marsh Farm viaduct was noted to be poorly drained during the walkover. There may be a diffuse discharge of groundwater into this valley bottom from an inlier of Sherwood Sandstone to Berkswell Marsh SSSI as well as from the superficial sand and gravel deposits.

Historical occurrence of groundwater flooding

6.3.20 SMBC's SFRA identifies a number of historical flooding events due to a combination of surface water and river flooding. However there are no known problems with flooding from groundwater within 1km of the route centre line within the Solihull Metropolitan Borough.

Current groundwater flood risk

6.3.21 The superficial deposits along the CFA23 route are mainly free draining sands and gravels. The River Terrace deposits, Glaciofluvial deposits and Arden Sandstone are designated as Secondary A aquifers.

6.3.22 Groundwater strikes from available borehole logs and monitoring instrumentation show that water strikes predominate from near the Shadow Brook underbridge to the northern limit of CFA23, in the area of the Glaciofluvial outcrop. To the south of the area, groundwater is poorly recorded in the borehole logs, but near surface water levels can be expected in the River Blythe floodplain and the southern Glaciofluvial outcrop. The Bromsgrove Sandstone (Sherwood Sandstone Group) is designated a Principal aquifer but is not intersected by the proposed route.

6.3.23 Although there are areas of permeable superficial deposits associated with rivers and watercourses where relatively shallow groundwater levels are expected, the current level of groundwater flood risk is considered low, this is supported by information that there are no reported historical groundwater flooding incidents on record.

6.4 Artificial sources / infrastructure failure

6.4.1 Artificial sources of flood risk describe a mechanism whereby the source of flooding would be failure of infrastructure used to impound (reservoir), retain (dam) or convey water (water pipeline).

6.4.2 In CFA23 flooding is a realistic possibility from the failure of the following infrastructure:

- surface water sewerage systems;
- foul water sewerage systems;
- water supply pipe networks; and
- reservoir failure.

6.4.3 The nearest canal to the CFA23 proposed route and infrastructure is the Grand Union Canal which follows a general north to south route some 3.6km to the west of the route centre line at its closest point. The canal is predominantly in cutting or grade and is not considered to pose a significant flood risk to the Proposed Scheme.

Water supply network

6.4.4 Water mains and water distribution infrastructure are a potential source of flood risk in the event of a failure. This section identifies significant water mains within the network and their position relative to the proposed route for the baseline condition.

6.4.5 Significance of the water main is based on diameter and pressure. It is assumed that the majority of small diameter pipes within the network are of low risk as the rate at which water escapes will be low. Where the risk is not considered to be low the utility is presented in Figure 10 and Figure 11.

Figure 10: Balsall Common water mains

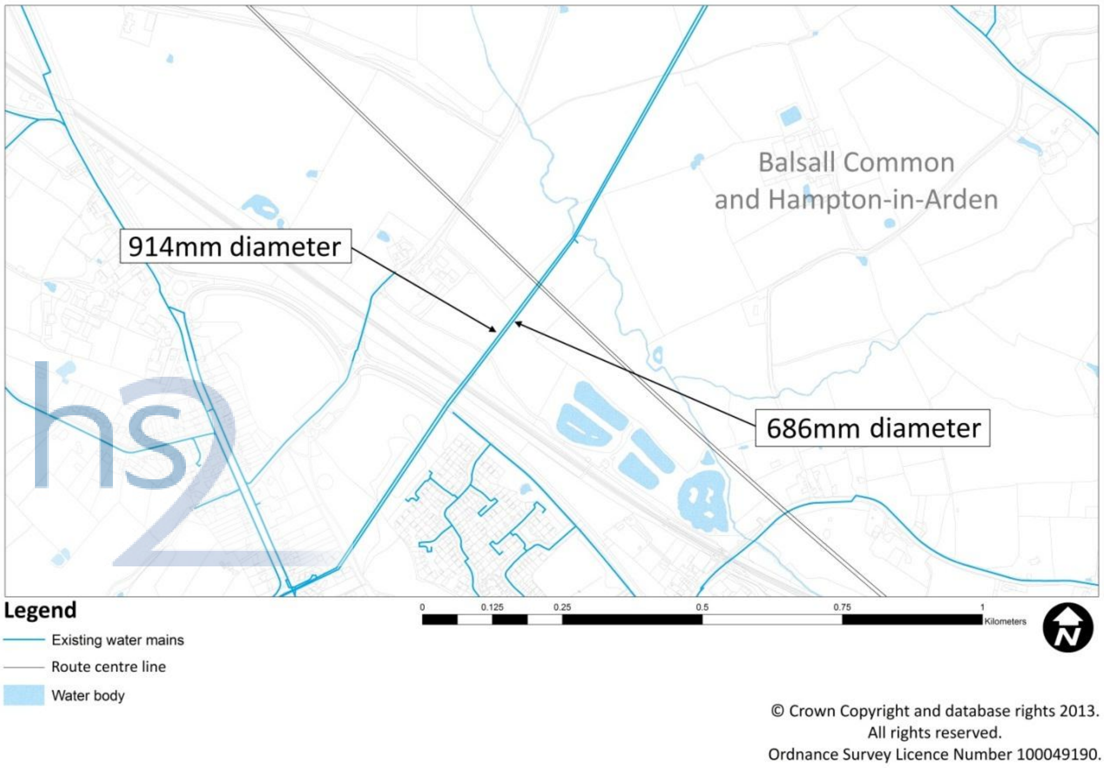
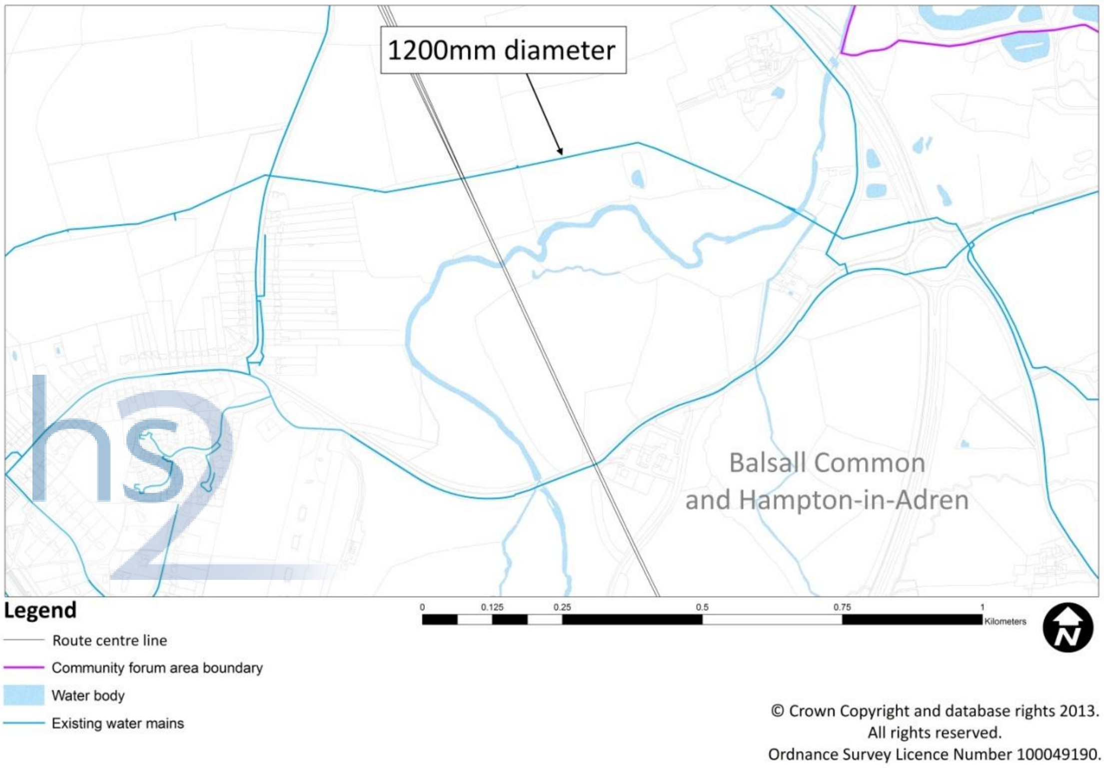


Figure 11: Blythe Valley water mains



6.4.6 An assessment of how existing water supply infrastructure interacts with the Proposed Scheme has been undertaken.

Reservoir failure

6.4.7 The probability of flooding occurring from the failure of a reservoir or large water body created by impoundment of water, by a dam or other retaining structure is extremely low. The Environment Agency's website reports that there has been no loss of life due to reservoir failure in the UK since 1925. All large water bodies across the UK have to be maintained and monitored to a very high standard under the Reservoir Act 1975[24]. This requires regular inspection of any water body designated a reservoir by a nominated engineer. However if a reservoir does fail the impact is likely to be severe and far reaching. It is a requirement of NPPF and The Flood and Water Management Act 2010[25] to evaluate the implications of reservoir failure on all proposed development even if the likelihood is very low. The Flood and Water Management Act 2010 proposes to change the capacity threshold at which reservoirs are regulated from 25,000m^3 to 10,000m^3. Secondary legislation which has yet to be enacted is required to enforce this change.

6.4.8 Although impounded water bodies with a capacity less than 10,000m^3 are not within the Reservoir Safety Act, they may still pose a significant flood risk and such water bodies are discussed in this chapter where appropriate.

6.4.9 The Environment Agency's Reservoir Inundation mapping for the Warwickshire area has been compared to the route within the study area.

6.4.10 There are three water bodies that are identified on the Environment Agency Reservoir Inundation maps as posing a flood risk to the River Blythe catchment in the vicinity of the proposed route. These are listed below:

- Earlswood lakes (including Engine Pool, Windmill Pool and Terry's Pool) located approximately 12km South West of the proposed route. These reservoirs are owned and maintained by the Canal Trust and are feeder reservoirs for the Stratford Upon Avon Canal. The flood pathway from these lakes would convey water along the River Blythe channel to the River Blythe viaduct approximately 26km downstream from the lakes;
- Meriden No. 1 and Meriden No. 2 Service Reservoirs are located approximately 4.2km from the proposed route. These reservoirs are owned and maintained by the Severn Trent Water. The flood pathway from the reservoirs would convey water through the village of Meriden and into the watercourse referred to as the River Blythe bypass in this report; and
- Geary's Level and Molands lakes, Packington, which are located less than 1km from the route and in close proximity to the Meriden Road. The lakes are owned and maintained by the Packington Estate Enterprises Ltd. The River Blythe is situated between the lakes and any proposed route infrastructure.

24. Reservoir Safety Act, (1975), London, Her Majesty's Stationary Office.

25. The Flood and Water Management Act, (2010), London, Her Majesty's Stationary Office.

6.4.11 The Environment Agency's Reservoir inundation food mapping shows the largest area that might be flooded if a reservoir were to fail. In most areas in vicinity to the River Blythe crossing the extent of inundation would be less extensive than the 1% AEP flood event as identified by the Environment Agency's Flood Mapping. However, the Environment Agency's data provided does not indicate flood depths, flow velocities or the time taken for onset of flooding after a breach takes place.

6.4.12 The mapping indicates that in the event of a catastrophic failure of any of the reservoirs in the Blythe catchment listed above the flood waters would flow down the rivers channels and extend out across the floodplain of both river systems.

6.4.13 In addition to the water bodies described above there are a number of smaller lakes and ponds which could pose a flood risk to the proposed route but which are not included in the reservoir mapping.

6.5 Summary of baseline flood risk

Table 15: Summary of baseline flood risk for all sources of flooding in CFA23

Source of flooding	Location of flooding source	Flood risk category	Elements at risk	Assessment of risk
Rivers	River Blythe	Low to Very High Flood Zone 1 – 3b	Proposed Scheme including River Blythe viaduct, Patrick embankment and Diddington Lane embankment	The route runs in close proximity and crosses the River Blythe and so crosses all flood zones. Proposed Scheme set at above 0.1% AEP flood level plus appropriate freeboard. As such the Proposed Scheme is at low risk from the River Blythe.
	Shadow Brook	Low to Very High Flood Zone 1 – 3b	Proposed Scheme including Shadow Brook underbridge and embankments	The route runs in close proximity and crosses Shadow Brook and so crosses all flood zones. Proposed Scheme set at above 0.1% AEP flood level plus appropriate freeboard. As such the Proposed Scheme is at low risk from Shadow Brook.

Source of flooding	Location of flooding source	Flood risk category	Elements at risk	Assessment of risk
	Horn Brook / River Blythe Bypass	Low to Very High Flood Zone 1 – 3b	Proposed Scheme including River Blythe Bypass culvert and embankments	The route runs in close proximity and crosses The River Blythe Bypass and so crosses all flood zones. Proposed Scheme set at above 0.1% AEP flood level plus appropriate freeboard. As such the Proposed Scheme is at low risk from the River Blythe Bypass
		Low to Very High Flood Zone 1 – 3b	A452 Kenilworth Road Diversion	The highway route runs in close proximity and crosses The Horn Brook and so crosses all flood zones. The level of the road is above the 1% +CC modelled flood levels plus the minimum freeboard requirements and as such is at low risk from the Horn Brook
	Bayleys Brook	Low to Very High Flood Zone 1 – 3b	Proposed Scheme, Balsall Common viaduct, Marsh Farm viaduct, Lavender Hall Lane culvert and embankments	The route runs in close proximity and crosses Bayleys Brook in two locations and so crosses all flood zones. Proposed Scheme set at above 0.1% AEP flood level plus appropriate freeboard. As such the Proposed Scheme is at low risk from Bayleys Brook.
			Truggist Lane and Birmingham to Rugby Line	Balsall Comon viaduct will convey flow up to 1% AEP plus climate change and replacement floodplain storage has been provided. No significant increase in flood risk.

Source of flooding	Location of flooding source	Flood risk category	Elements at risk	Assessment of risk
	Unnamed Tributary	High	Proposed Scheme in cutting	Watercourse diversion appropriately sized and local protection to Proposed Scheme will be provided.
Surface water	Proposed Scheme drainage systems	Low	Land adjacent to receiving watercourses	Proposed Scheme drainage will be attenuated to pre-development greenfield/brownfield run-off rates within balancing ponds prior to discharge.
	Lavender Hall Lane and Park Lane diversion	Low	Land adjacent to Bayleys Brook.	Additional run-off from diversions will be attenuated to pre-development greenfield/brownfield run-off rates within balancing ponds prior to discharge.
	A452 Kenilworth Road	Low	Land adjacent to Horn Brook	No increase in paved area as a result of diversion so no significant increase in flood risk.
Artificial sources	Waterbodies contributing to the River Blythe and Horn Brook catchment. Earlswood lakes, Meriden No. 1 and Meriden No. 2 Service Reservoirs, Geary's Level and Molands lakes	Low - pathway exists within existing 1% AEP river flood flow	Proposed Scheme (embanked and viaducts)	Rail level set at >1m above 0.1% river flood level

Source of flooding	Location of flooding source	Flood risk category	Elements at risk	Assessment of risk
Groundwater	Superficial deposits overlying the Tile Hill Mudstone from Lavender Hall Lane overbridge to the Heart of England Way bridge	Medium -high High groundwater levels within Secondary A Aquifer	Park Hall Cutting	No historical incidents of groundwater flooding
Groundwater	Superficial deposits overlying the Mercia Mudstone at Pasture Farm overbridge	Medium -high High groundwater levels within Secondary A Aquifer	Diddington Cutting	No historical incidents of groundwater flooding
Surface water	Kenilworth Greenway	Low	Beechwood embankment	Rail level is >1m above 0.1% AEP
Surface water	Rugby to Birmingham line	Low	Proposed Scheme	Rail level is >1m above 0.1% AEP
Surface water	A452 Kenilworth Road	Low	Diverted A452	The road is embankment and a culvert provided to allow passage of surface water flow.

Source of flooding	Location of flooding source	Flood risk category	Elements at risk	Assessment of risk
Surface water	A45 Coventry Road	Low	Proposed Scheme (Diddington Cutting)	Additional run-off from increased paved areas attenuated to greenfield run-off rates within balancing ponds prior to discharge to minor unnamed watercourse

7 Flood risk management measures

7.1.1 The purpose of this FRA is to demonstrate the flood risk impact of the Proposed Scheme within CFA23.

7.1.2 In this study area, the Proposed Scheme does result in some increases in flood depth and extent in some locations, however the FRA demonstrates that this does not significantly increase flood risk elsewhere and that the Proposed Scheme can be implemented without putting proposed infrastructure at risk of flooding.

7.1.3 In the first instance the risk of flooding from rivers and streams has been assessed and the water level generated by the 0.1% AEP river flood events has been calculated, with an allowance for blockage of existing culverts and bridges. The rail level will be set a minimum of 1m above this level, or a flood protection structure will be provided.

7.1.4 To do this a number of physical mitigation measures have had to be included in the design to either safeguard adjacent land users or the Proposed Scheme and associated infrastructure. These physical measures are described below.

7.1.5 Flood alleviation culverts will be provided at Lavender Hall embankment.

7.1.6 Partial replacement floodplain storage will be provided at Lavender Hall embankment, Lavender Hall Lane, Marsh Farm viaduct, River Blythe viaduct and Shadow Brook underbridge.

7.1.7 Surface water management across CFA23 will be provided to collect and convey surface water away from the Proposed Scheme and adjacent third party land vulnerable to flooding (water sensitive properties and infrastructure) up to the 0.1% AEP rainfall event. To achieve this on site flows will be strictly regulated by implementing attenuation storage and off site receptors will be considered in the event of rainfall events that exceed the design standard.

8 Post-development flood risk assessment

8.1 River flood risk

River Blythe

8.1.1 The key design elements with potential river flood risk considerations associated with the River Blythe catchment are:

- a viaduct crossing of the River Blythe;
- modifications to Stonebridge Island adjacent to the River Blythe; and
- a new junction on the A452 Kenilworth Road diversion adjacent to the River Blythe.

River Blythe viaduct crossing

8.1.2 The route crosses the River Blythe channel and floodplain between B4102 Meriden Road and the A452 Kenilworth Road, approximately parallel to the route of the A452 Kenilworth Road. The route will cross the floodplain on a 6 span, 150m long, viaduct.

8.1.3 The River Blythe viaduct has been incorporated into the baseline river hydraulic model of the River Blythe to produce a post-development model. The full range of flood events (50%, 20%, 10%, 2%, 1% and 1% plus climate change) have been simulated within this model to determine the impact caused by the Proposed Scheme on the performance of the River Blythe for a range of flood conditions.

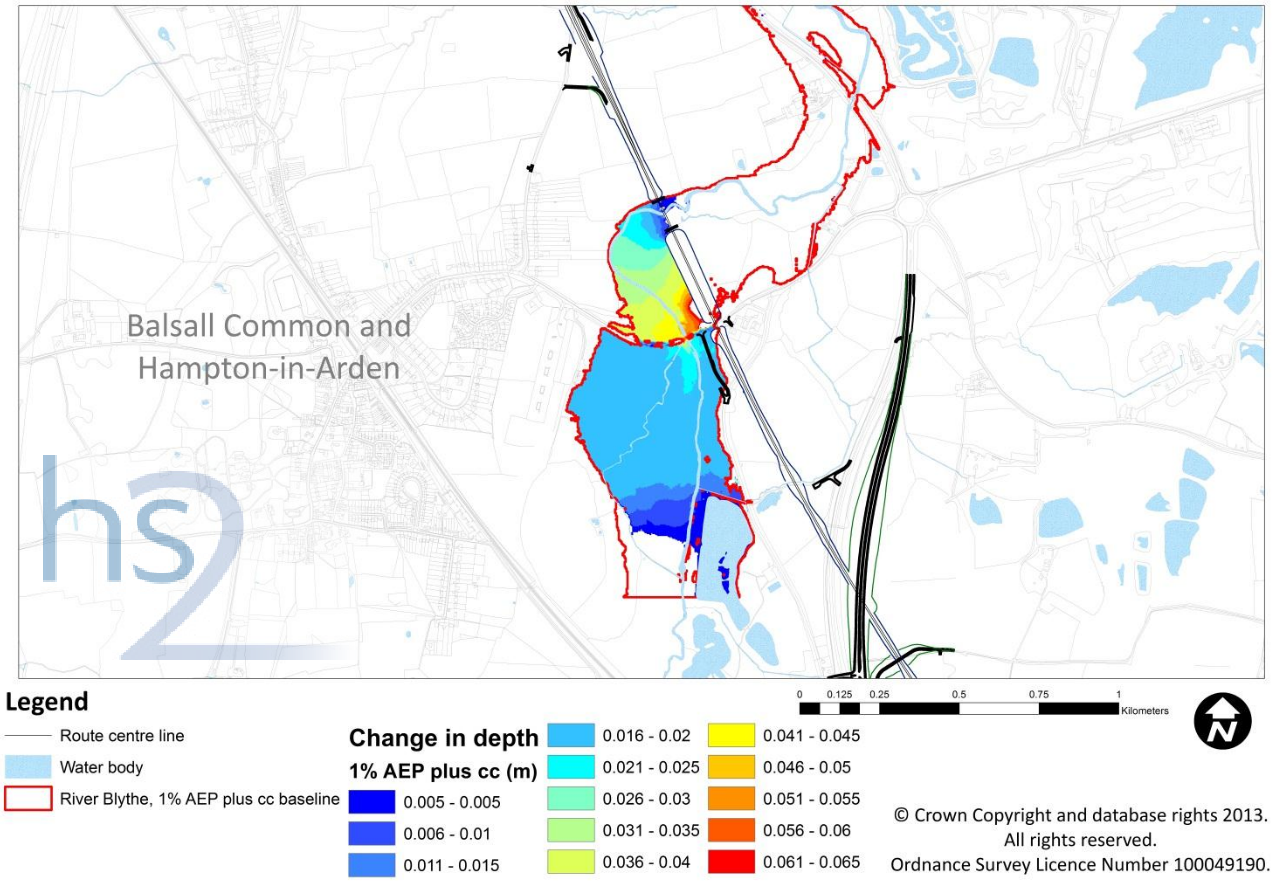
8.1.4 The River Blythe viaduct has been modelled with four clear spans of 25m and two partially obstructed spans to represent the abutments of the Diddington Lane and Patrick embankments. Each pier has been modelled as a 3m wide pier due to the grid size.

8.1.5 The impact of the Proposed Scheme on the River Blythe flood levels and flooded extents for the 1% AEP plus CC event is discussed in detail. The impact on lower return period flood events are only discussed if the nature of the Proposed Scheme infrastructure may increase flood risk during less extreme events but not cause a significant impact at the 1% AEP plus CC event.

8.1.6 The 0.1% AEP flood level is referenced to determine the risk to the Proposed Scheme only.

8.1.7 The change in flood depths between the post-development and baseline models are shown in Figure 12 for the 1% AEP plus CC. Where there is less than 1mm increase in flood depth between baseline and post development, this has not been shown. Where there is a depth increase greater than 60mm this has also been removed as these are due to changes in flood extent, i.e. areas of new flooding, which can be seen on Volume 5: Map book WR-05.

Figure 12: Flooding extents for the River Blythe post-development model with change to peak water level – 1% AEP + CC



8.1.8 Upstream of the B4102 Meriden Road, there will be an increase in flood levels (typically 20mm or less at the 1% AEP plus CC event, but directly upstream of the B4102 Meriden Road the increases are up to 35mm) on agricultural land and a marginal increase to flood extent (0.3% of the baseline flood extents) due to the Proposed Scheme. This land already floods under current baseline conditions and the Proposed Scheme will not change the frequency or the duration of flooding at this location.

8.1.9 Downstream of the B4102 Meriden Road, between this and the Proposed Scheme, there are increases on agricultural land of approximately 45mm or less at the 1% plus climate change event. There are also increases in flood extent (approximately 1% of the baseline flood extents) around the perimeter of the baseline flood extent. There is a localised increase in upstream flood level of approximately 150mm (at the 1% AEP plus CC event) due to the Patrick embankment obstructing the flow path. There are also localised increases on the upstream side of the piers on the right hand floodplain caused by flow path obstruction. These localised increases are replicated at lower return periods but do not exceed 70mm – there is no change to flood frequency or duration.

8.1.10 The B4102 Meriden Road has increased flood levels of up to 60mm for the 1% AEP plus CC simulation and small increases in flood extent (approximately 3% of the baseline flood extent). This road is flooded in the baseline to levels of approximately 300mm at the 1% AEP plus CC event. The increase in flooding does not alter the hazard classification[26] of the road under flood events. The depth and velocity of baseline flooding predicted by the model for the 1% AEP plus CC event corresponds with a hazard rating of "danger to most", the changes to flood depth and velocities as a result of the scheme is insufficient to cause a change in this hazard rating. There is no significant change to flood duration or frequency.

8.1.11 Downstream of the Proposed Scheme there is no change in flood depths or extent up to the 1% AEP plus CC.

8.1.12 Typical changes in depths have been recorded in Table 16.

Table 16: Typical changes in depth from the River Blythe post-development model

Location	**Typical change in depth (mm)**
Localised area adjacent to Patrick embankment	150
Between B4102 Meriden Road and the Proposed Scheme	45
B4102 Meriden Road	60
Upstream of B4102 Meriden Road	20

8.1.13 The post development model predicts a minor increase in peak flows immediately downstream of the route at the A452 Kenilworth Road crossing for the 50%, 10%, 1% and 1% AEP plus CC events with the increase being a maximum 0.025m^3/s or 0.1% (for the 50% AEP peak flow).

8.1.14 The flood risk receptors identified as being inundated for the baseline conditions (section 6.1.17) do not show any increase in flood risk or extent for any return period event.

8.1.15 The rail level of the Proposed Scheme will be designed to be protected from the 0.1% AEP, which includes simulated blockage of the downstream bridge and viaduct. Along the River Blythe viaduct the lowest top of rail level is ~94m AOD, 8m above the 0.1% AEP flood level of 86.04m (including blockage analysis).

8.1.16 The Proposed Scheme will result in lost flood storage as a result of the embankments and viaduct piers which encroach on the 1% AEP + CC floodplain. All modelling results assume that this lost flood storage will not be entirely replaced; however, the Proposed Scheme includes an area of partial replacement floodplain storage to be located adjacent to the watercourse on the left bank. This requirement for which will be confirmed at detailed design in consultation with the Environment Agency.

[26] DEFRA, (2005) Flood risk assessment guidance for new development, Phase 2, R&D Technical report FD2302/TR2, Defra - Flood Management Division

8.1.17 The Proposed Scheme includes the closure of Diddington Lane, which is an alternative to Meriden Road for accessing Hampton-in-Arden. The closure of Diddington Lane has the potential to impact on emergency access and egress routes during flood events as Meriden Road, in baseline and post-development, may be impassable at certain flood events. Alternative access routes are available. During the detailed design stage consultation will be held with the Environment Agency and the LLFA to agree suitable flood warning and evacuation plans to mitigate this closure and ensure that emergency access routes are maintained.

Stonebridge island modifications (A45 / A452)

8.1.18 The Stonebridge Island modifications will include revised filter lanes onto the A45 Coventry Road.

8.1.19 The location is beyond the limits of the River Blythe model created to assess the impact of River Blythe viaduct and the potential flood risk impact has been assessed by comparing the Environment Agency's flood zone mapping with earthwork profiles to determine whether any loss of flood storage and change to flood flows could occur.

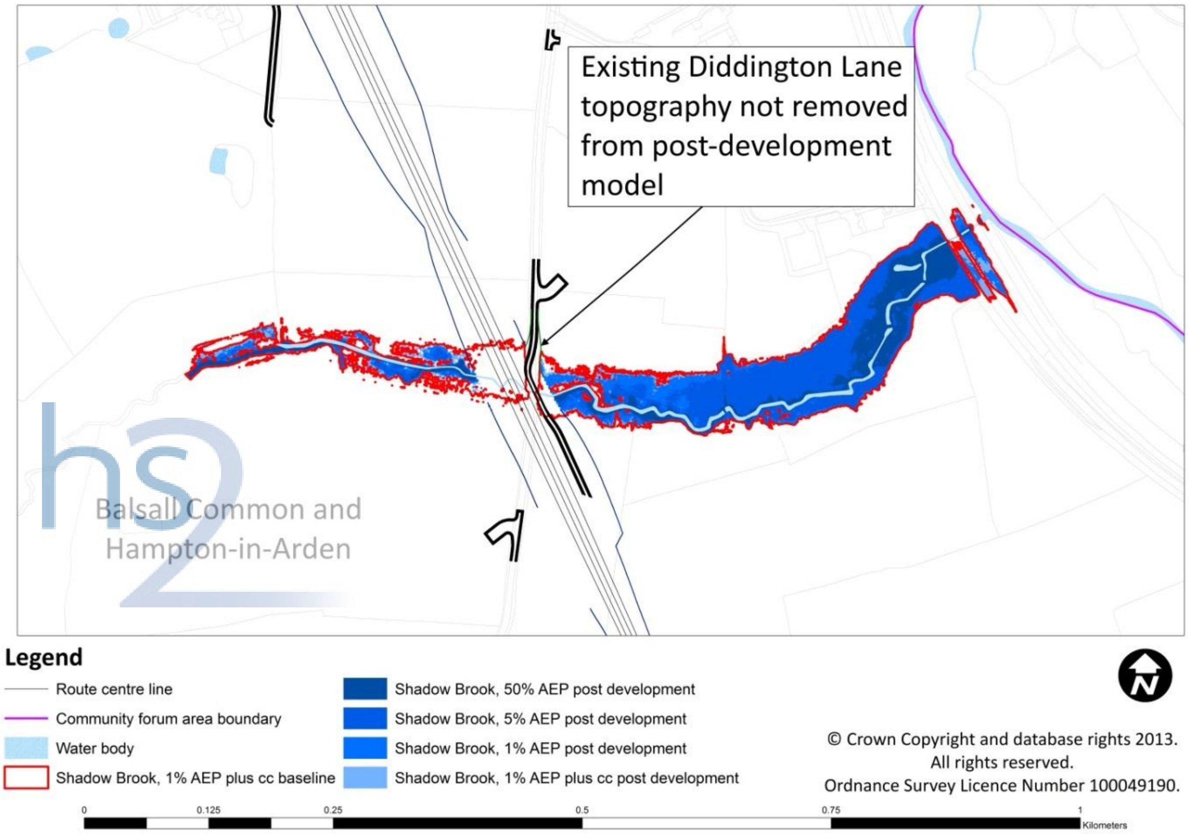
8.1.20 The assessment indicates that the earthworks will be generally outside of the floodplain extents even allowing for an additional factor of safety applied to flood levels to account for uncertainty in the derivation of levels. However, part of the existing A452 Kenilworth Road slip road will be within the Environment Agency's Flood Zone 3 extent due to a low point in the vertical alignment. There is no significant change to flood risk in this area.

Shadow Brook

Shadow Brook underbridge crossing

8.1.21 The route will cross Shadow Brook and its associated floodplain at the existing Diddington Lane crossing. The route will cross the watercourse via a Shadow Brook underbridge. A plan showing the proposed crossing is included in Table 13.

Figure 13: Plan of Shadow Brook underbridge flood mapping



8.1.22 The proposed bridge has been incorporated into the baseline river hydraulic model of the Shadow Brook to produce a post-development model. The existing Diddington Lane culvert and road profile has been removed from the model as Diddington Lane will be closed. The full range of flood events has been simulated within this model to assess changes in flood risk.

8.1.23 Flood extents for a range of return periods up to the 1% AEP + CC are shown in Figure 13. Flood maps for the 5% AEP and 1% AEP plus CC events are provided in Volume 5: Map book WR-05 and WR-06.

8.1.24 The relative changes in water level between the baseline model and the post-development model are presented in Table 17.

Table 17: Shadow Brook proposed flood levels (m) (for cross-section locations see Volume 5: Appendix WR-004-018 Section 3)

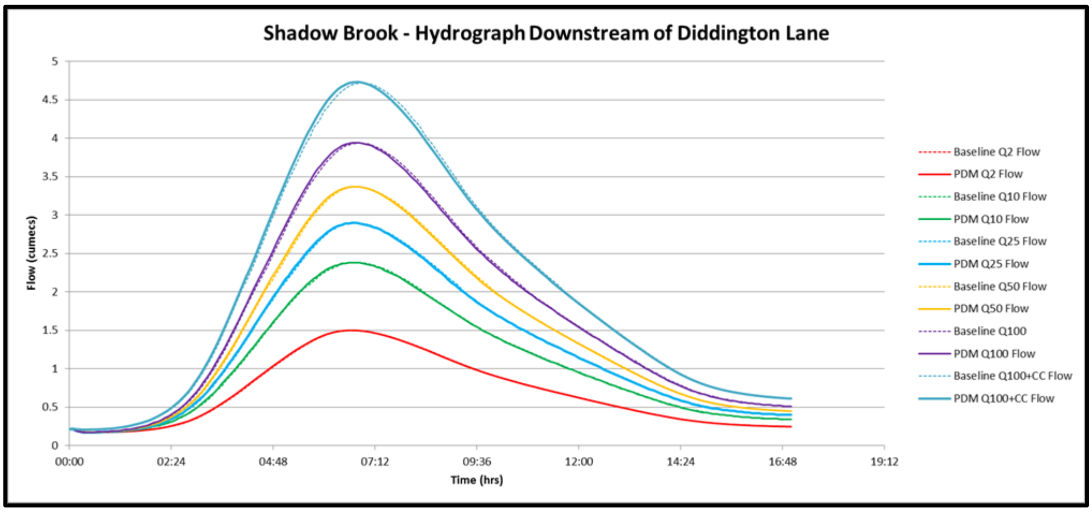
	AEP					
Proposed Scheme Feature	**50%**	**10%**	**5%**	**2%**	**1%**	**1% plus CC**
Baseline at model cross-section 713	84.96	85.114	85.176	85.259	85.326	85.413
Post-development upstream of channel diversion at model cross-section 713	84.972	85.109	85.158	85.224	85.275	85.335
Change	0.012	-0.005	-0.018	-0.035	-0.051	-0.078

8.1.25 The post-development model indicates a decrease in flood levels upstream of the proposed diversion for flood events in excess of the 50% AEP event. There is a minor, localised increase in flood levels for the 50% AEP event. The decrease at the higher return period events is attributed to the removal of the existing restriction caused by the Diddington Road level and culvert crossing. The predicted backwater effect of the changes in water level extends less than 100m upstream and do not significantly alter the flood extents.

8.1.26 A one dimensional unsteady state model has been created to assess the potential downstream impacts associated with the removal of the existing Diddington Lane culvert. The modelling approach is based on a single duration hydrograph assessment for selected return periods. The duration is based on the ReFH recommended storm duration.

8.1.27 Figure 14 identifies the comparative change in flow immediately downstream of Diddington Lane. For the 1% AEP plus CC flow there is a minor <1% increase in downstream flows as a result of the development with the removal of the Diddington Lane culvert and road profile.

Figure 14: Baseline and post-development hydrographs for Shadow Brook



8.1.28 Flood protection to the Proposed Scheme is assessed in relation to the 0.1% AEP. Proposed route alignment top of rail level at this location is approximately 92.75m AOD, 12.95m above the 0.1% AEP flood level of 85.696m which includes simulated blockage of the downstream bridge and viaduct.

8.1.29 There will be a loss of floodplain storage as a result of the embankment encroaching on the 1% AEP plus CC floodplain. The 1D modelling approach adopted for this crossing cannot accurately not take account of the lost flood storage, however, an area of replacement floodplain storage has been identified which will be located adjacent to the watercourse on a level for level basis. The requirement for this will be confirmed at detailed design in consultation with the Environment Agency.

Bayleys Brook

8.1.30 The route and associated highway diversions will cross Bayleys Brook at the following locations:

- Balsall Common viaduct;
- Lavender Hall Lane diversion;
- Marsh Farm viaduct; and
- A452 Kenilworth Road and the M218 bridleway diversion.

8.1.31 Individual models have been created at each location to assess the flood risk impacts and each crossing point is discussed separately in the following sections.

Balsall Common viaduct crossing

8.1.32 The route will cross Bayleys Brook and associated floodplain between Lavender Hall Lane and Truggist Lane. The route will cross the watercourse via a 250m long viaduct (Balsall Common viaduct) which will be constructed with 25m spans and approximately 2m wide piers. A localised brook diversion is required to convey the channel between piers because of the angle that the viaduct crosses the watercourse. There will be embankment to the west.

8.1.33 The Balsall Common viaduct has been incorporated into the baseline hydraulic model of Bayleys Brook to produce a post-development model. This model only considers three of the spans directly adjacent to the watercourse as the baseline flood extent modelled did not show flooding towards Truggist lane.

8.1.34 The post-development flood extents for a range of events up to the 1% AEP plus CC are shown in Figure 15 and the post development change in depth for the 1% AEP plus CC is shown in Figure 16.

8.1.35 Flood mapping (see Volume 5: Map book WR-05 and WR-06) shows increases in flood extent around the perimeter of the baseline floodplain, this is approximately equal to 8% of the area of the baseline flood extent at the 1% plus CC event. There are very localised increases of up to 270mm for the 1% AEP plus CC event due to ponding of water against the western embankment and around piers. There are also increases in flood depths to the adjacent agricultural land downstream of up to 150mm, but this decreases to no significant change within 300m downstream of the route. There is a small increase in flood extents to north around the perimeter of the baseline floodplain. The backwater effect of the increase (less than 20mm) extends no more than 130m upstream and does not reach to Truggist Lane. These have been summarised in Table 18.

8.1.36 The post development model predicts a minor decrease in peak flows immediately upstream of the proposed route of up to 2.0% for the 1% AEP plus climate change simulation. The increase is reduced to a negligible change at the downstream boundary condition. The typical change in peak flows for the range of return periods is ±1%.

8.1.37 The flood risk receptors identified as at risk of flooding for the baseline conditions do not demonstrate any noticeable increase in flood level for the range of return periods assessed. Localised upstream increases at piers and within the main channel are evident but these increases do not extend to the outer extremes of the floodplain.

8.1.38 The rail track will be protected from the 0.1% AEP event, which includes simulated blockage of the downstream bridge and viaduct. Along the Balsall Common viaduct the lowest proposed route alignment top of rail level is 112.170m AOD, 6.3m above the 0.1% AEP flood level of 105.84m (including blockage).

8.1.39 The Proposed Scheme will encroach on the 1% AEP plus climate change flood extent due to the Lavender Hall embankment and viaduct piers which. All modelling results assume that this lost flood storage will not be replaced; however, the Proposed Scheme will include an area of replacement floodplain storage which will be located adjacent to the watercourse. The requirement for this will be confirmed at detailed design in consultation with the Environment Agency.

Figure 15: Balsall Common viaduct post development flood map 1% AEP + 20% CC

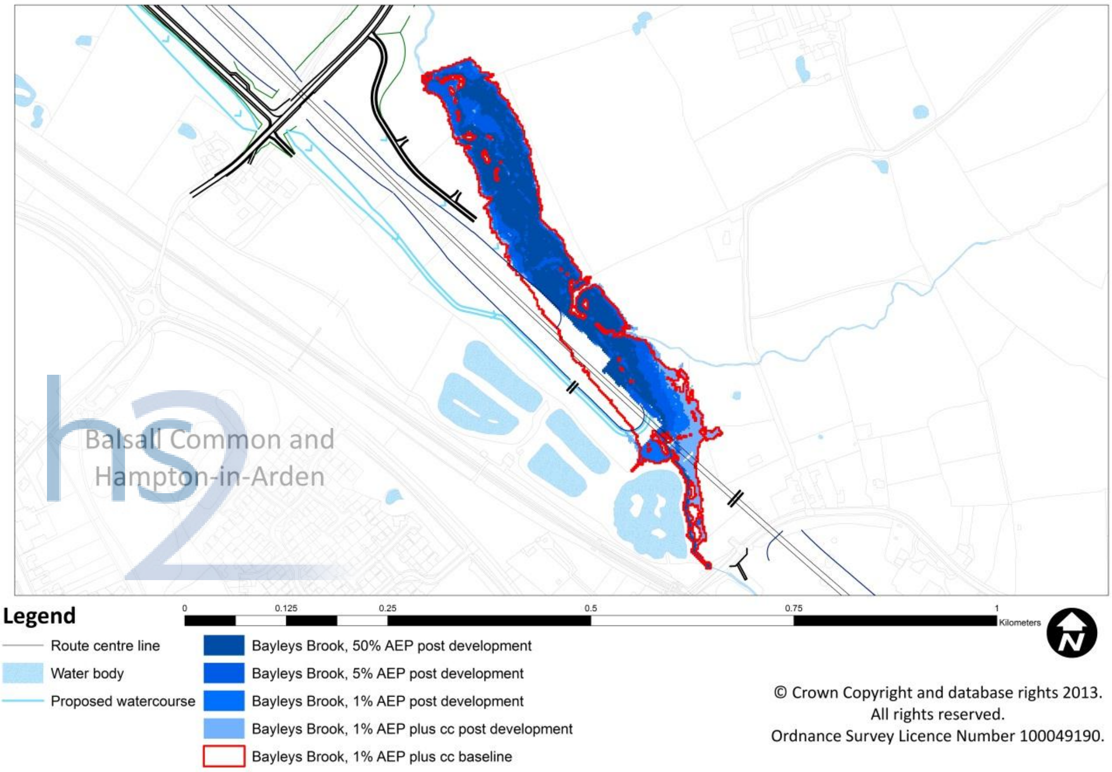


Figure 16: Balsall Common change in depth plan 1% AEP + 20% CC

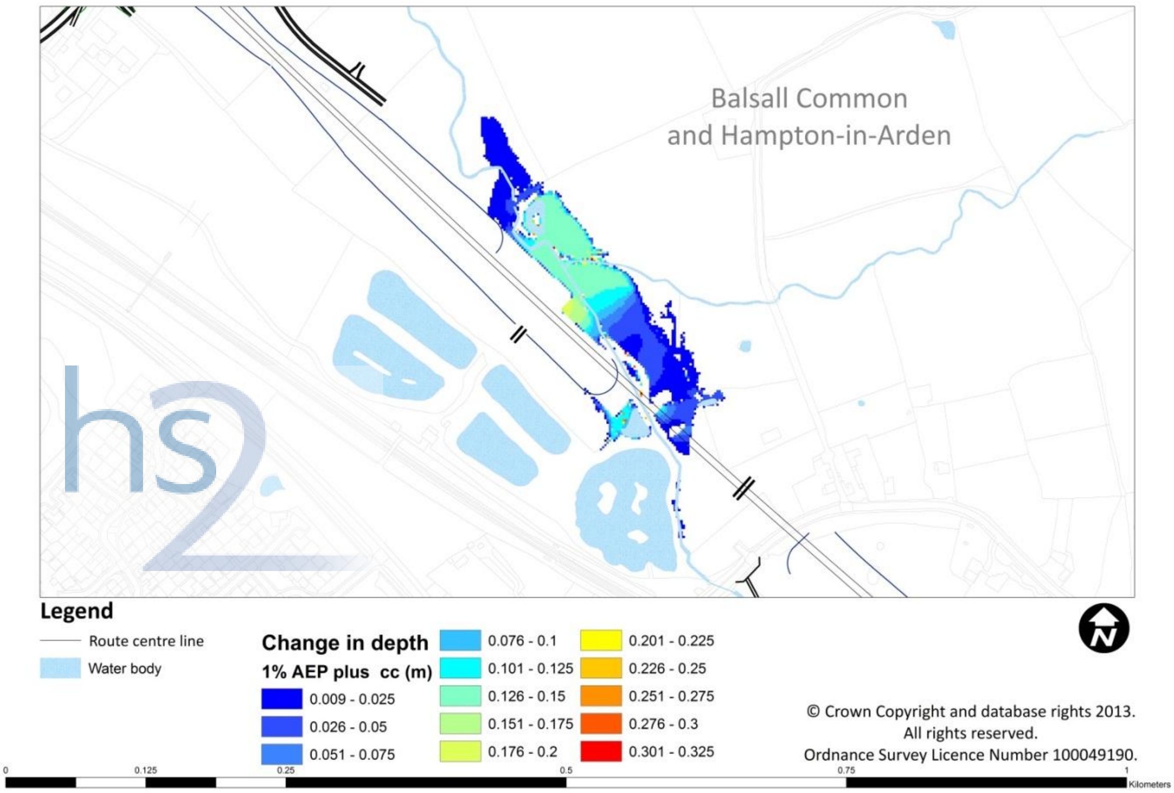


Table 18: Typical changes in depth on Bayleys Brook from the post development model

Location	Typical change in depth (mm)
At proposed route	270
Downstream	150
End of model extent	0

Marsh Farm viaduct crossing

8.1.40 The route will cross Bayleys Brook at Marsh Farm to the east of the A452 Kenilworth Road. The route will cross the watercourse via a 144m viaduct structure which will span the wide marshy floodplain.

8.1.41 The Marsh Farm viaduct has been incorporated into the baseline river hydraulic model of the Bayleys Brook to produce a post-development model. The proposed A452 Kenilworth Road diversion is also included. The full range of flood events have been simulated within this model to determine the impact caused by the Proposed Scheme on the performance of Bayleys Brook at Marsh Farm.

8.1.42 The post development model flood extents for the 5% AEP and 1% AEP plus CC are included in Volume 5: Map book WR-05 and WR-06. The flood extents for a range of return periods are shown in Figure 17.

8.1.43 The relative changes in water level between the baseline model and the post-development model are presented in Table 19.

Figure 17: Marsh Farm viaduct post development flood map

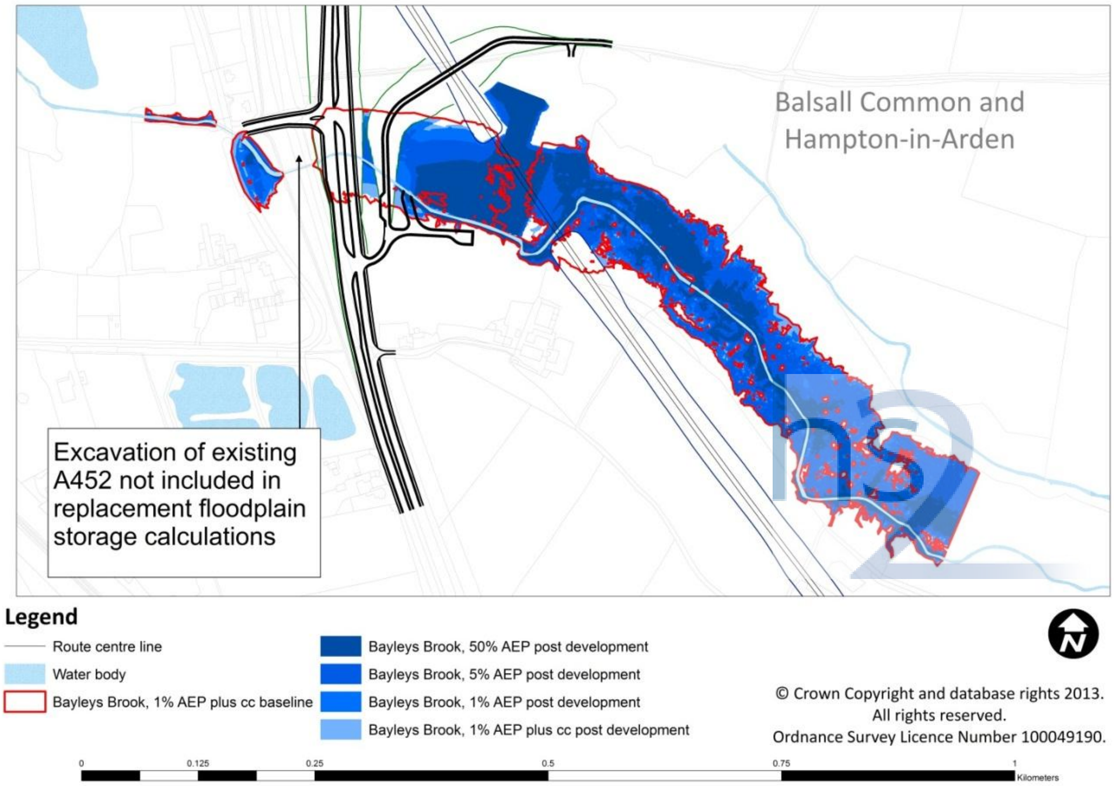


Table 19: Marsh Farm viaduct crossing Bayleys Brook flood levels (m) (for cross-section locations see Volume 5: Appendix WR-004-018 Section 6)

	AEP					
Proposed Scheme Feature	**50%**	**10%**	**5%**	**2%**	**1%**	**1% plus CC**
Downstream cross-section 8.2 – baseline	89.744	89.828	89.858	89.895	89.937	90.058
Downstream cross-section 8.2 – post-development	89.708	89.815	89.855	89.921	89.991	90.106
Cross-section 8.2 - change	-0.036	-0.013	-0.003	0.026	0.054	0.048
Upstream cross-section 8.4 – baseline	90.521	90.594	90.645	90.676	90.71	90.734
Upstream cross-section 8.4 – post-development	90.521	90.59	90.642	90.673	90.712	90.74
Cross-section 8.4 - change	0.000	-0.004	-0.003	-0.003	0.002	0.006
Upstream cross-section 11 – baseline	90.788	90.842	90.875	90.903	90.938	90.968
Upstream cross-section 11 – post development	90.788	90.842	90.875	90.903	90.938	90.968
Cross-section 11 – change	0.000	0.000	0.000	0.000	0.000	0.000
Adjacent to alignment cross-section 12 - Baseline	90.996	91.035	91.061	91.086	91.12	91.151
Adjacent to alignment cross-section 12 – post-development	90.996	91.035	91.061	91.086	91.12	91.151

	AEP					
Proposed Scheme Feature	**50%**	**10%**	**5%**	**2%**	**1%**	**1% plus CC**
Cross-section 14 – change	0.000	0.000	0.000	0.000	0.000	0.000

8.1.44 In the vicinity of the Marsh Farm viaduct crossing the post-development model indicates a localised increase in flood levels and extents on existing agricultural land under 1% AEP plus CC event. The viaduct is of sufficient length to ensure a negligible change in the upstream flood risk. There is a localised predicted increase in flood levels on agricultural land located between Marsh Farm viaduct and A452 Kenilworth Road occurring for the 2%, 1% and 1% AEP plus CC flood events, which at the 1% AEP event is 54mm . The predicted flooding occurs at a single cross section and is attributed to the change in downstream flood levels where the new A452 culvert capacity is increased, reducing upstream flood levels.

8.1.45 In this location proposed route alignment top of rail is 94.71m AOD, 3.79m above the 0.1% AEP flood level of 90.92m which includes simulated blockage of the downstream bridge and viaduct.

8.1.46 The Proposed Scheme development will result in lost flood storage as a result of the embankment encroaching on the 1% AEP plus 20% CC floodplain. The 1D modelling approach adopted for this crossing cannot accurately take account of the lost flood storage, however, an area of replacement floodplain storage is proposed to be located adjacent to the watercourse on a level for level basis. The requirement for this will be confirmed at detailed design in consultation with the Environment Agency.

A452 Kenilworth Road and bridleway diversion

8.1.47 The proposed A452 Kenilworth Road and Bridleway diversion crosses the Bayleys Brook immediately east (upstream) of the existing A452 Kenilworth Road which will be removed. The existing A452 Kenilworth Road and culvert are excavated out to provide additional capacity within the downstream network where there is a flood risk posed to the adjacent Mercote Lodge. The proposed culvert is modelled as a single 4.8m span structure, 85m in length. In practice the culvert can be separated into two separate structures with a considerably reduced length to maximise the extent of open watercourse and minimise lost floodplain storage.

8.1.48 The proposed road diversion and culvert have been incorporated into the baseline hydraulic model of the Bayleys Brook to produce a post-development model. The proposed A452 Kenilworth Road diversion is also included. The full range of flood events up to the 1% AEP plus CC have been simulated within this model to determine the impact on the performance of the Bayleys Brook.

8.1.49 Flood extents for the 5% AEP and the 1% AEP plus CC are in Volume 5: Map book WR-05 and WR-06. The flood extents for a range of return periods are shown in Figure 17.

8.1.50 The relative changes in water level between the baseline model and the post-development model are presented in Table 20.

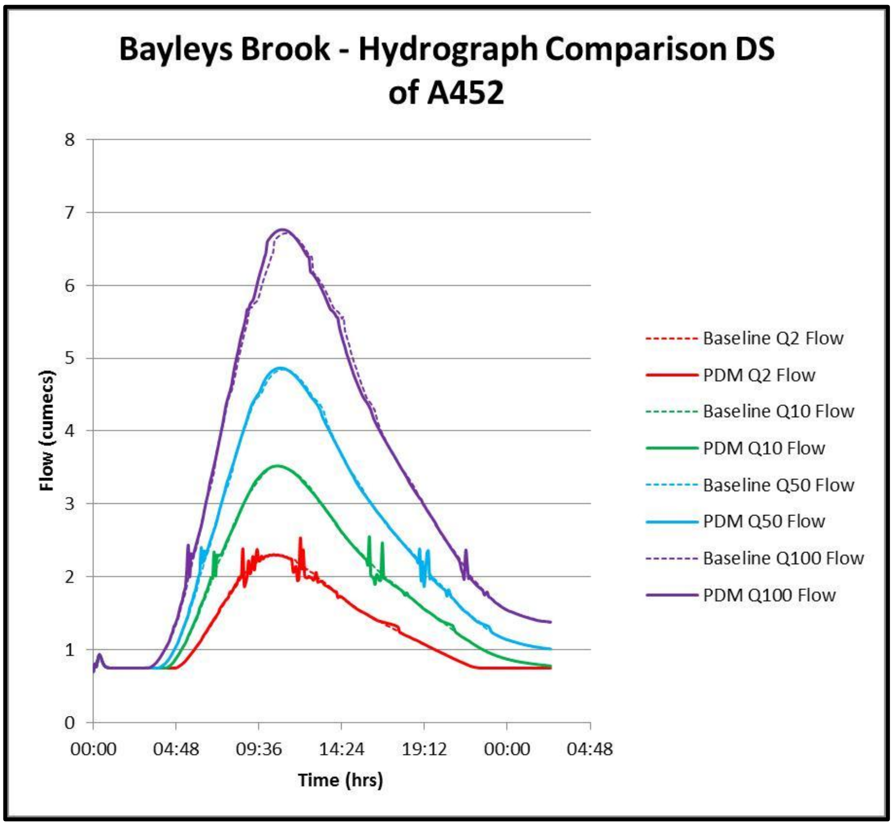
Table 20: A452 Kenilworth Road and Bridleway post-development flood levels (m) (for cross-section locations see Volume 5: Appendix WR-004-018 Section 6)

	AEP					
Proposed Scheme Feature	**50%**	**10%**	**5%**	**2%**	**1%**	**1% plus CC**
Upstream of Marsh Lane – baseline cross-section 6	88.804	88.935	89.026	89.112	89.377	89.534
Upstream of Marsh Lane – post-development cross-section 6	88.804	88.935	89.027	89.113	89.377	89.534
Cross-section 6 - change	0.000	0.000	0.001	0.001	0.000	0.000
A452 & Bridleway Diversion - upstream A452 baseline cross-section 8	89.605	89.672	89.704	89.707	89.741	89.843
A452 & Bridleway Diversion - upstream A452 post-development cross-section 8	89.443	89.498	89.551	89.609	89.735	89.849
Cross-section 8 – change	-0.162	-0.174	-0.153	-0.098	-0.006	0.006

8.1.51 The flood extents and flood levels indicate a significant reduction in flood levels upstream of the culvert structure of up to 175mm at lower return period flood events. The reduction results from an increase in culvert capacity.

8.1.52 The one dimensional models have been run in an unsteady state to provide an initial assessment of the potential downstream impacts associated with the increase in culvert capacity. The modelling approach is not documented in the modelling reports but includes a single duration hydrograph assessment for selected return periods. The duration is based on the ReFH recommended storm duration and further tests to determine the critical duration storm will be required as the design develops and detailed data becomes available. The hydraulic model does not represent the loss of storage due to the proposed route embankments or the associated replacement floodplain storage area. The graph below identifies the comparative change in flow downstream of the proposed culvert for a selection of return periods.

Figure 18: Hydrographs (baseline and post development) comparison downstream of the A452 Kenilworth Road



8.1.53 For the 1% AEP plus CC flow there is a predicted <1% (<0.1m^3/s) increase in downstream flows as a result of the removal of the railway culvert and embankment. At the 50% AEP event the change in flow is negligible apart from a model instability error in the post development model.

8.1.54 The unsteady state model predicts only a minor increase in flood level (<10mm) downstream of the A452 Kenilworth Road culvert. This is primarily due to the influence of the Marsh Lane culvert on flood levels on the downstream side of the A452 Kenilworth Road.

8.1.55 Notwithstanding the above it is noted that further development of the hydraulic model is required as part of the detailed design to confirm the potential impact on downstream flows analysed as part of the initial assessment.

8.1.56 The Proposed Scheme will include embankment which will encroach on the 1% AEP plus CC floodplain, and reduce the available floodplain storage. The one dimensional modelling approach adopted for this crossing cannot accurately take account of the lost flood storage; however, an area of replacement floodplain storage is proposed to be located adjacent to the watercourse on a level for level basis which provides storage in combination with the channel diversion.

Lavender Hall Lane diversion

8.1.57 The proposed Lavender Hall Lane diversion will cross the Bayleys Brook channel and floodplain immediately upstream of the existing Lavender Hall Lane. The proposed road alignment will be elevated above the floodplain on embankment and will cross the proposed route via an over bridge to the south-west of the Bayleys Brook crossing. Bayleys Brook will be conveyed beneath the Lavender Hall Lane diversion through a central 5.5m span, 50m long culvert with two 2m span flood relief culverts provided to convey extreme flood flows without increasing upstream flood levels. The existing Lavender Hall Lane will be retained as a private access and the existing culvert will be retained.

8.1.58 The proposed road alignment and culverts have been incorporated into the one dimensional baseline hydraulic model of the Bayleys Brook to produce a post-development. The full range of flood events has been simulated within this model to assess changes in flood risk.

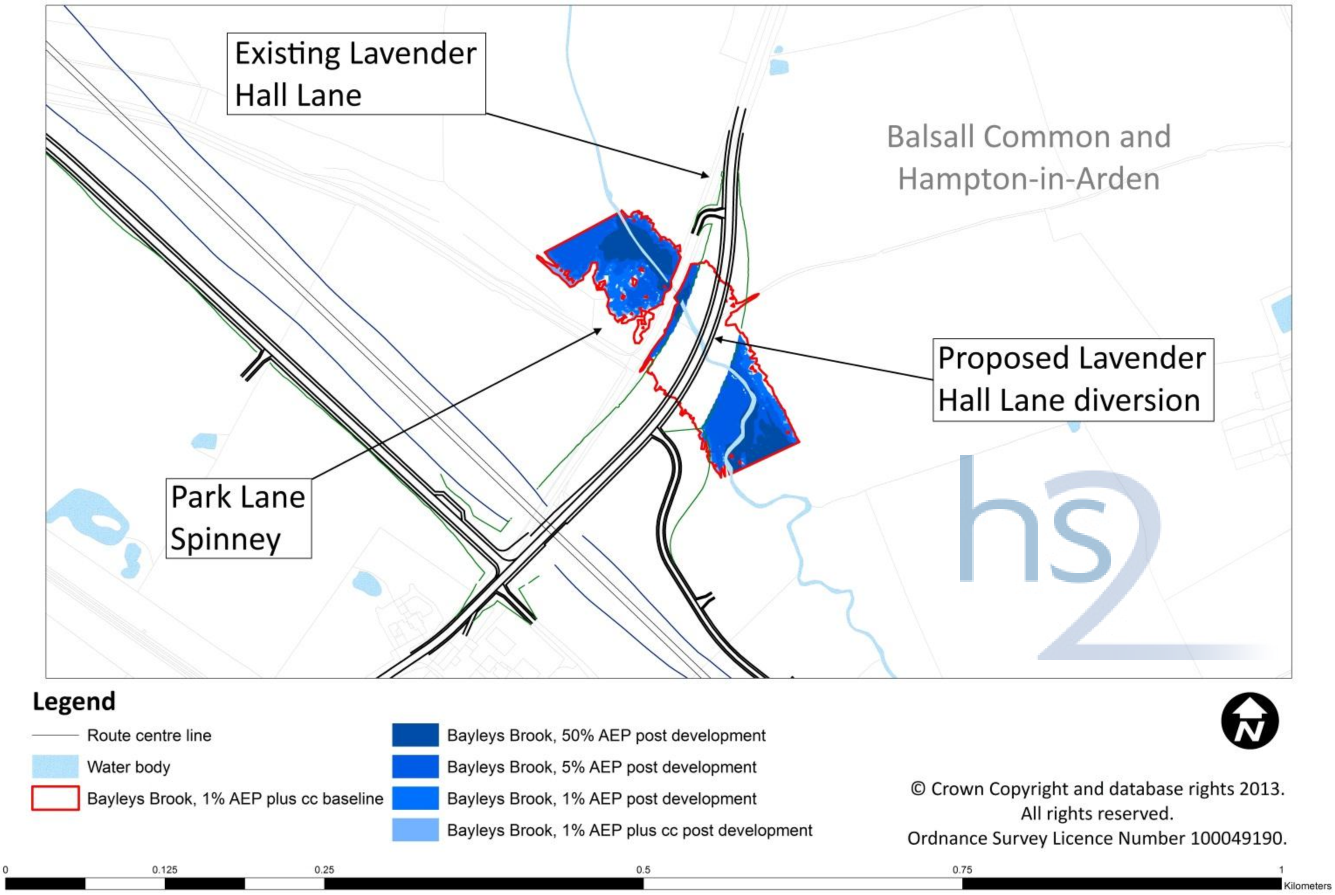
8.1.59 The post-development flood extents for the 5% AEP and 1% AEP plus CC are provided in Volume 5: Map book WR-05 and WR-06. A range of modelled flood extents for the post-development case are provided in Figure 19 .

8.1.60 The relative changes in water level between the baseline model and the post-development model are presented in Table 21.

Table 21: Bayleys Brook, Lavender Hall Lane - proposed flood levels (m) (for cross-section locations see Volume 5: Appendix WR-004-018 Section 5)

	AEP					
Proposed Scheme Feature	**50%**	**10%**	**5%**	**2%**	**1%**	**1%plus CC**
Upstream of Lavender Hall Lane cross-section 4	102.05	102.198	102.302	102.405	102.412	102.448
Upstream of Lavender Hall Lane post development cross-section 4	102.044	102.212	102.315	102.422	102.434	102.467
Change	-0.006	0.014	0.013	0.017	0.022	0.019
Upstream of Lavender Hall Lane cross-section 5	102.445	102.481	102.479	102.517	102.55	102.603
Upstream of Lavender Hall Lane post development cross-section 5	102.451	102.487	102.501	102.552	102.585	102.641
Change	0.006	0.006	0.022	0.035	0.035	0.038

Figure 19: Lavender Hall Lane post-development flood mapping



8.1.61 Upstream of the proposed A452 Kenilworth Road diversion for all return periods apart from the 50% AEP event, the mapping and flood levels indicate an increase in depth of up to 40mm on agricultural land that already flood under baseline conditions, and no increase in extents. The increase is greater for the higher return periods and diminishes under more frequent events where the inflows are lower. The Proposed Scheme will result in lost flood storage as a result of the embankment located within the floodplain. The one dimensional modelling approach adopted for this crossing cannot accurately take account of the lost flood storage; however, an area of replacement floodplain storage is proposed to be located adjacent to the watercourse on a level for level basis.

River Blythe Bypass

River Blythe Bypass viaduct

8.1.62 The route will cross the River Blythe Bypass channel and floodplain. The alignment will be elevated above the floodplain and a culvert will be provided to provide a flow route beneath the Blythe Bypass embankment.

8.1.63 The River Blythe Bypass culvert has been incorporated into the baseline hydraulic model of the River Blythe Bypass to produce a post-development model. The full range of flood events has been simulated within this model to assess changes in flood risk.

8.1.64 The post development flood extents are provided in Volume 5: Map book WR-05 and WR-06. A range of flood extents from the post development model are shown in Figure 20. The accompanying modelling report (Volume 5: Appendix WR-004-018) shows the flood outline to the east of the A452 Kenilworth Road this has been omitted from Figure 20 and the flood maps Volume 5: Map book WR-05 and WR-06 DTM in this area was not of sufficient quality to generate accurate mapping.

8.1.65 The relative changes in water level between the baseline model and the post-development model are presented in Table 22.

Figure 20: River Blythe Bypass post-development flood extents

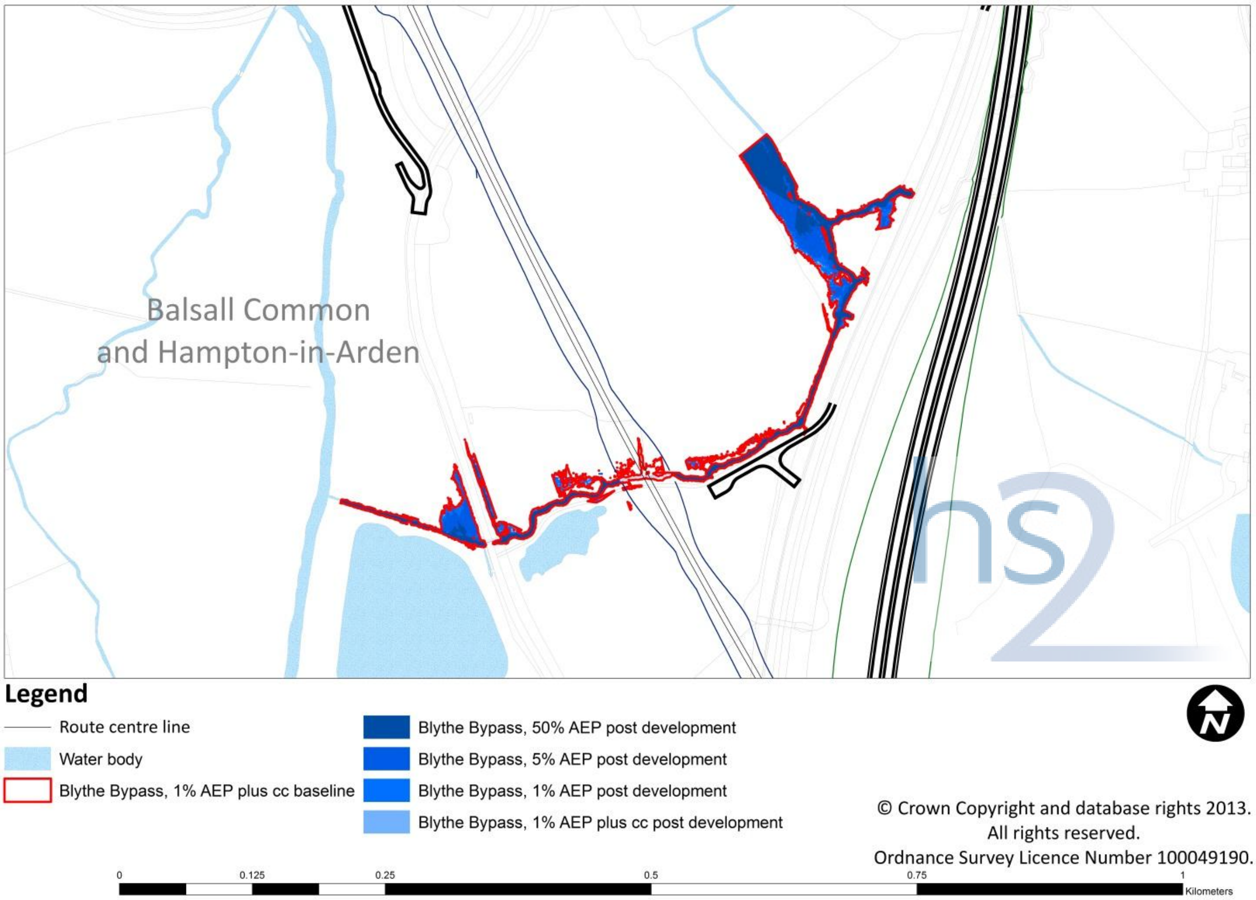


Table 22: River Blythe Bypass post development flood levels (m)

	AEP					
Proposed Scheme Feature	**50%**	**10%**	**5%**	**2%**	**1%**	**1% plus CC**
Upstream baseline cross-section 355	86.222	86.327	86.376	86.407	86.438	86.471
Upstream post-development cross-section 355	86.222	86.323	86.373	86.404	86.437	86.47
Change	0	-0.004	-0.003	-0.003	-0.001	-0.001

8.1.66 The post-development model indicates a negligible increase in flood levels upstream of the River Blythe Bypass culvert for all return periods. Where there is an increase in floodplain extent, the impact is negligible with no significant impact on flood receptors.

8.1.67 The proposed alignment is to be protected from the 0.1% AEP, which includes simulated blockage of the downstream bridge and viaduct. Along the River Blythe Bypass viaduct the lowest proposed route alignment top of rail level is approximately 92m AOD, 4.79m above the 0.1% AEP flood level of 87.284m.

Other tributaries

Post development assessment method

8.1.68 The post-development assessment for the small tributary (Figure 21) has been undertaken using the CIRIA guide C689.

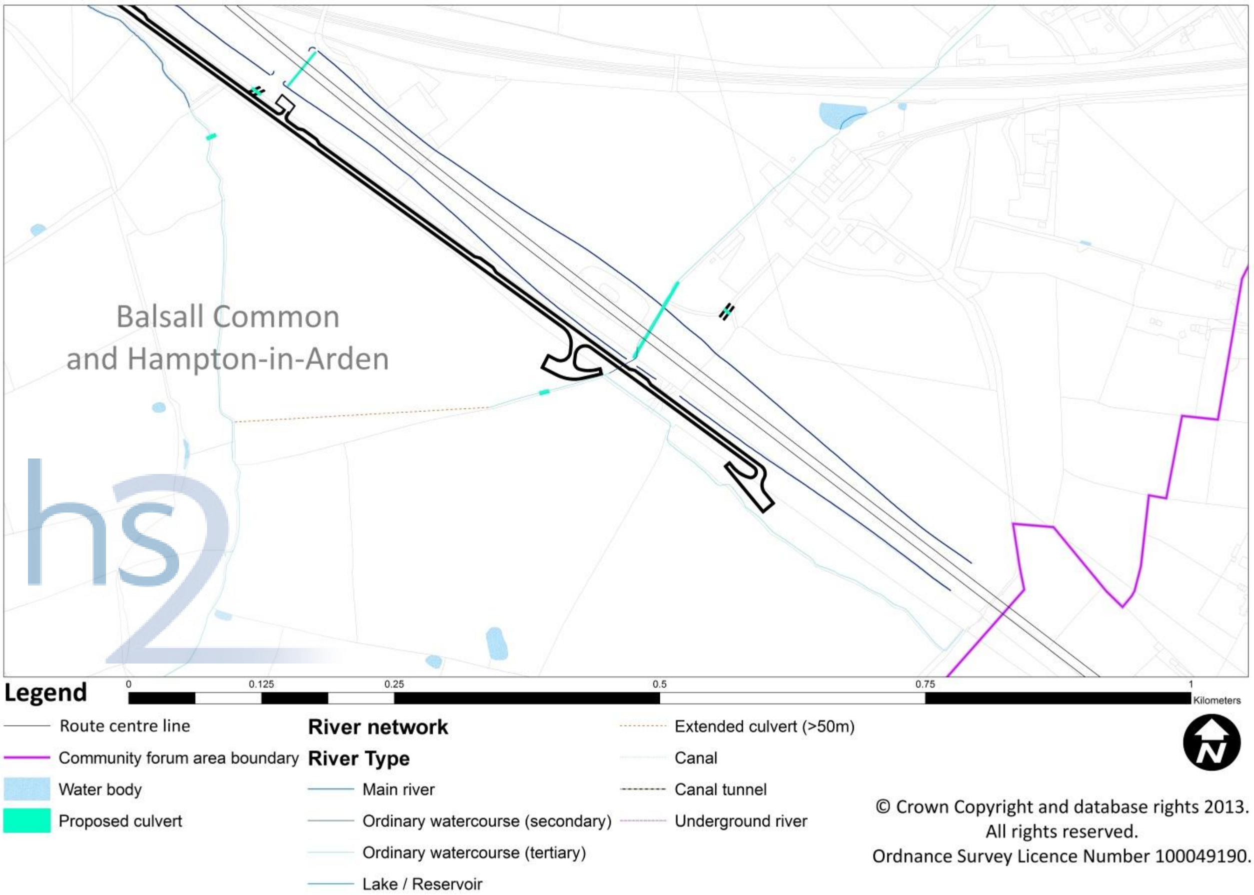
8.1.69 The approach calculates the culvert dimension required to convey the 1% AEP flood flow including a 30% allowance for climate change. The culvert is designed to convey the flood flow while maintaining a minimum 600mm freeboard to soffit. By providing a culvert sufficiently sized to convey the 1% AEP flood flow the impact on upstream flood level increases is controlled.

8.1.70 The culvert method does not take account of a backwater affect from downstream structures. The method is used to primarily assess the conveyance capacity of the culvert

8.1.71 No allowance has been made for the installation of trash screens or security gratings on culverts.

8.1.72 The predicted upstream flood level derived using the culvert assessment methods are shown below along with a description of the development proposals.

Figure 21: Watercourse crossing at Beechwood Farm



8.1.73 This un-named watercourse will be crossed by the route perpendicular to the channel. There is an existing culvert located downstream of the proposed route crossing which passes beneath an abandoned railway embankment (now part of the Kenilworth Greenway).

8.1.74 A 4m span x 2.7m deep box culvert (Beechwood culvert) will convey the watercourse beneath the Proposed Scheme. The resultant upstream flood level is predicted to be 112.85m AOD. In comparison, the upstream Beechwood Farm development is located at an elevation of at least 113.00m AOD. The Beechwood Farm accommodation underpass will be constructed alongside the culvert which will be located at an elevation approximately equal to the 1% AEP flood level using CIRIA Report C689. The underpass will operate as an informal flood relief culvert. The culvert calculations ignore the potential attenuating effect of the existing Rugby to Derby Line culvert upstream of Beechwood embankment. Therefore, there is no significant flood risk predicted to Beechwood Farm up to the 1% AEP plus CC event.

8.2 Surface water and sewerage flood risk

Proposed Scheme drainage

8.2.1 Surface water run-off from the Proposed Scheme will be attenuated to balance peak run-off rates and volumes to pre-development levels for a range of return periods up to the 1% AEP (+30% allowance for climate change). Based on the available information at this time and due to high groundwater levels, it is deemed unlikely that infiltration techniques will be a viable method of surface water disposal in this section of the route, therefore within this study area all the Proposed Scheme rail drainage systems will discharge to watercourses.

8.2.2 Drainage interception and conveyance designs will utilise a combination of piped track drainage and open channels which will convey drainage flows to balancing ponds while protecting the route from flooding up to the 0.1% AEP year storm event.

8.2.3 Ponds are the preferred method of flow attenuation due to the linear nature of the project and the requirement to control run-off at managed discharge points (design drawings are shown in Volume 2: Map book CT-06).

8.2.4 The Proposed Scheme drainage catchments are listed in Table 23 and shown in Annex A of this report.

Table 23: Proposed Scheme drainage catchments and outfalls

Linear km of route drained	Receiving watercourse	Watercourse status	Greenfield peak discharge rate Q100 (l/s/ha)*	Outfall number
0.430	Unnamed	Ordinary	2.60-12.55	O-1479
0.350	Unnamed	Ordinary	2.86 - 12.55	O-1483
0.500	Bayleys Brook	Ordinary	3.29 - 12.55	O-1492
3.340	Bayleys Brook	Ordinary	2.60 - 12.55	O-1526
0.950	River Blythe Bypass	Ordinary	2.60 - 12.55	O-1534
0.880	River Blythe	Main	2.60 - 12.55	O-1538
0.650	Shadow Brook	Ordinary	2.60 - 12.55	O-1549
0.660	Shadow Brook	Ordinary	2.60 - 12.55	O-1552

*Greenfield peak discharge Q100 rate is derived from QBAR estimation for rural catchments, Institute of Hydrology Report 124 (1993)[27]. Attenuation volumes have been provisionally sized on the lower value and further site investigation will be required to confirm actual discharge rates at the detailed design stage.

27. Marshall, D.W.C. and Bayliss, A.C., (1993), *Flood Estimation for Small Catchments report number 124*, Natural Environment Research Council.

Highway drainage

8.2.5 Throughout the study area, the route requires the diversion or replacement of a number of existing public highways. The associated highway drainage systems will be reconfigured or replaced.

8.2.6 Drainage of reconfigured highways will aim to replicate the existing highway drainage strategy and outfalls. Where the paved area of the highway has been increased, highway run-off will be collected from an area equivalent to the additional paved surface and attenuated to balance peak run-off rates and volumes to pre-development levels for a range of return periods up to 1% AEP (+30% allowance for climate change). It is deemed unlikely that infiltration techniques will be a viable method of surface water disposal in this section of the route.

8.2.7 Ponds are the preferred method of flow attenuation due to the linear nature of the project and the requirement to control run-off at managed discharge points (design drawings are shown in Volume 2: Map book CT-06).

8.2.8 The highway drainage catchments are listed in Table 24 below and shown in Annex A of this report.

Table 24: Highway drainage catchments and outfalls

Existing area of highway drained (ha)	Proposed area of highway drained (ha)	Net change in highway drained (ha)	Receiving watercourse	Greenfield peak discharge rate Q100 (l/s/ha)*	Outfall No.
0.825	1.164	+0.339	Bayleys Brook	10.18 - 12.55	O-1500
1.489	1.728	+0.239	Bayleys Brook	No attenuation proposed as decrease in overall impermeable area	O-1527
2.123	1.732	-0.391	Unnamed watercourse		O-1535
0.547	0.420	-0.127	River Blythe	-	O-1542
	0.361	+0.361	River Blythe	10.18 - 12.55	O-1556
2.739	2.515	-0.224	River Blythe	-	O-1557
	0.308	+0.308	River Blythe	11.97 - 12.55	O-1559

*Greenfield peak discharge Q100 rate is derived from QBAR estimation for rural catchments, Institute of Hydrology Report 124 (1993)[28]. Attenuation volumes have been provisionally sized on the lower value and further site investigation will be required to confirm actual discharge rates at the detailed design stage.

28. Marshall, D.W.C. and Bayliss, A.C., (1993), *Flood Estimation for Small Catchments report number 124*, Natural Environment Research Council.

Surface water flow catchments

8.2.9 The route will introduce a continuous linear feature that will have the potential to interrupt and divert existing drainage catchments and surface water flow paths.

8.2.10 Where the route is on embankment or in cutting (including retained cutting) and the adjacent land falls towards the route (or there are existing urban drainage systems that may divert flows towards the route), a cut off drainage system and threshold protection measures will be provided to intercept the flows from external catchments and divert them to the nearest crossing point of the route, typically a bridge or culvert conveying a watercourse under the route.

8.2.11 Intercepted flows in the study area will be conveyed via grass lined ditches to outfall to a watercourse at a location as close to existing flow path as possible. The grass lined ditch will be graded to provide slow time of travel, so that time of entry to the watercourse will not be increased significantly, thereby minimising any effect on the watercourse.

8.2.12 The design assesses catchments and surface water flow paths in the baseline and post-development case to ensure no increase in flood risk to adjacent properties and receptors upstream or downstream of the Proposed Scheme.

8.2.13 An initial assessment of surface water flow catchments which will be modified as a result of the Proposed Scheme are shown in the figures presented in Annex A of this report. Where catchment flow paths are intersected by the Proposed Scheme, the design, where possible, will replicate existing catchment distributions and minimise alterations to surface water flow paths from their existing routes. Where this is not possible, a safe and secure route for drainage systems and surface water flows has been identified such that there will be no increased flood risk to properties or businesses. Flows will be intercepted using cut-off ditches and conveyed to a suitable outfall location as indicated on the Volume 2: Map book CT-06.

8.2.14 Catchments with notable issues are described in more detail in the following sections.

Sub-catchment 1A

8.2.15 The route will cross the line of existing flow paths to a channel running along Kenilworth Greenway. These flows will be intercepted within a cut-off ditch along the toe of the proposed embankment and conveyed in a similar manner as existing to an unnamed watercourse, approximately 50m upstream of current location with negligible impacts. The area is identified as susceptible to surface water ponding by the Environment Agency surface water flood maps but the provision of a drainage ditch at the toe of the Beechwood embankment will improve drainage in this area.

Sub-catchment 2D

8.2.16 This catchment is to west of the Rugby to Birmingham Line and naturally drains towards Bayleys Brook. This natural flow path is bisected due to the Proposed Scheme. In order to intercept and convey the run-off, a cut-off ditch will be provided to run from the high point southwards to outfall to Bayleys Brook. This cut-off ditch will protect the Proposed Scheme and the re-aligned Park Lane from surface water flooding, whilst also providing storage attenuation for the highway run-off (see Table 24 outfall O-1500).

8.2.17 In the baseline case, surface water flow would discharge to Bayleys Brook over a length of approximately 600m. Due to the Proposed Scheme this will result in the flow being introduced to Bayleys Brook at a point location. As flows will be attenuated within the cut-off ditch, the effects of the slightly altered flow path will be negligible subject to the correct implementation of all mitigation measures.

Sub-catchment 3A

8.2.18 A long, relatively thin surface water flow catchment will be intercepted by Park Lane cutting and Sixteen Acre Wood embankment along with a local drainage channel. In order to protect the cutting from surface water flows, a cut-off ditch will be provided to run along the west side of the route in order to provide a gravity outfall to Bayleys Brook. The cut-off ditch will be naturally lined and profiled in order to provide storage and attenuation of flows along its length.

8.2.19 The collected surface water flows, and land drainage ditch will discharge to Bayleys Brook up to 1.5km downstream of existing discharge locations. This will slightly decrease flows within Bayleys Brook along this location, but due to the relatively small intercepted catchment, the flood risk impact is deemed to be negligible.

Sub-catchment 4A

8.2.20 The existing flow paths cross the line of re-aligned A452 Kenilworth Road where a low point in the topography is identified as being a large at risk of ponding from surface water flow on the Environment Agency's surface water mapping. The area of surface water identified on the surface water mapping may be overestimated as there is likely to be a means of draining the area into the drainage channel on the opposite side of the A452 Kenilworth Road.

8.2.21 For post-development flows will be intercepted by a ditch at the toe of proposed Kenilworth Road embankment and conveyed to outfall close to the existing outfall location with negligible impacts.

Sub-catchment 5A

8.2.22 Surface water flows will be collected in cut-off ditch along toe of highway embankment and the Proposed Scheme to outfall to River Blythe similar to existing flow paths with negligible impacts.

Sub-catchment 5B

8.2.23 Surface water flows will be collected in cut-off ditch along toe of highway embankment and the Proposed Scheme to outfall to Shadow Brook similar to existing flow paths with negligible impacts.

Sub-catchment 5C

8.2.24 Surface water flows will be collected in cut-off ditch located along toe of proposed highway embankment to outfall to River Blythe similar to existing flow paths with negligible impacts.

Sub-catchment 5D

8.2.25 Flow paths will cross line of proposed B4102 Meriden Road/ Diddington Lane diversion. Surface water flows to be intercepted by cut-off ditch and conveyed through embankment in culvert to outfall to River Blythe at similar location to existing with negligible impacts.

Sub-catchment 5E and 5F

8.2.26 The Proposed Scheme will run parallel with existing surface water flow paths. A cut-off drainage ditch will be provided along toe of Proposed Scheme's embankment in order to collect any localised surface water drainage flows, and convey northwards to existing outfall location to Shadow Brook with negligible impacts.

Sub-catchment 6A

8.2.27 Surface water flows to be collected in cut-off ditch along toe of railway embankment to outfall to Shadow Brook similar to existing flow paths with negligible impacts.

Sub-catchment 6B

8.2.28 Flow paths which will cross the line of the Proposed Scheme will be intercepted by cut-off ditch and conveyed northwards to outfall to Hollywell Brook approximately 300m upstream of existing with negligible impact due to relatively small catchment area.

8.3 Groundwater

8.3.1 It is assumed that the principal mechanism by which Proposed Scheme will increase groundwater flood risk, is where impermeable structures (e.g. lined tunnels and pile walls) act as a barrier to groundwater flow and have the potential to cause a rise in groundwater level with mounding in the vicinity of these structures. Other changes to the groundwater environment such as through drained cuttings are not assumed to increase the groundwater flood risk as the drainage design will take account of groundwater flows entering the cutting.

8.3.2 To assess the possible changes to groundwater levels and flows, and the associated change in groundwater flood risk, a high level assessment of the groundwater conditions along the route has been undertaken to understand where the Proposed Scheme is likely to interact with groundwater (i.e. it is on an aquifer and within the proximity of groundwater levels).

8.3.3 This qualitative assessment has reviewed areas which have the potential to impact on groundwater flood risk and are discussed in Section 6.3.8. Further field data collection and analytical or numerical modelling will be required to quantify this change.

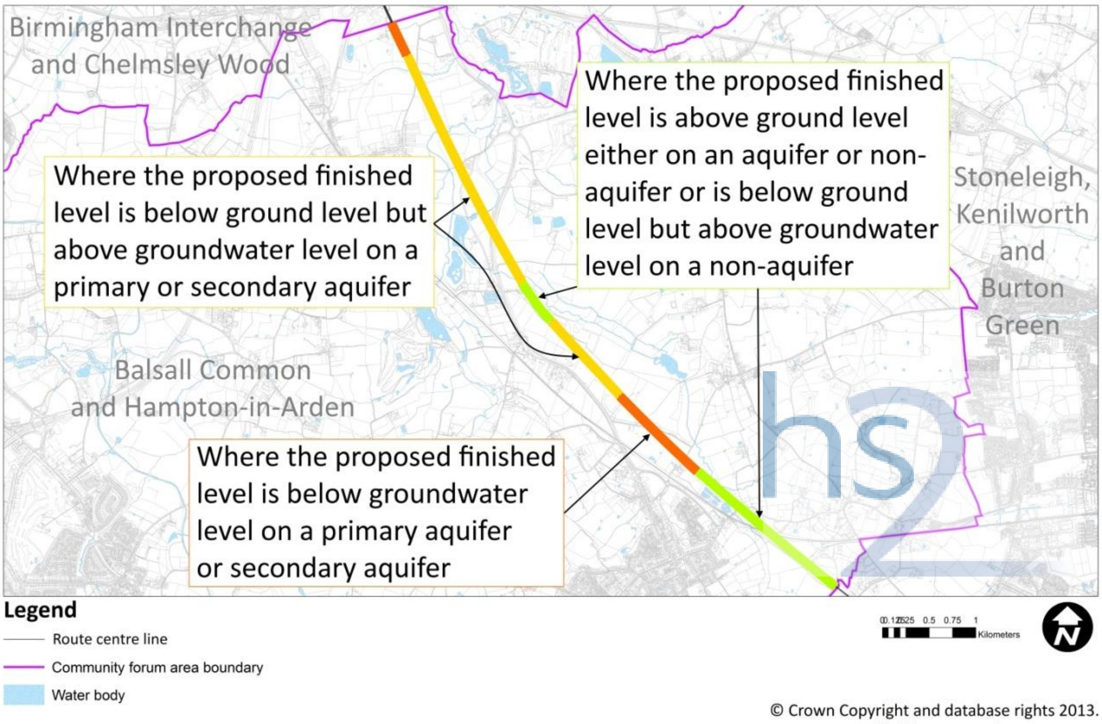
8.3.4 Table 25 shows the criteria used to identify areas where changes to the level of groundwater flood risk along the route corridor may occur from the introduction of Proposed Scheme infrastructure.

Table 25: Criteria to identify areas where changes to groundwater flood risk may occur

Low	Where the proposed finished level is above ground level either on an aquifer or non-aquifer or is below ground level but above groundwater level on a non-aquifer
Medium	Where the proposed finished level is below ground level but above groundwater level on a primary or secondary aquifer
High	Where the proposed finished level is below groundwater level on a primary or secondary aquifer

8.3.5 Information presented in Table 26 and summarised in Figure 22, illustrate the areas within CFA23 where there is greater potential for changes to groundwater flood risk post to the development and elsewhere.

Figure 22: Areas of greater potential for changes to groundwater flood risk within CFA23



8.3.6 The main areas where groundwater flood risk may be increased is where the Proposed Scheme will be within an aquifer and below groundwater level, and even then it depends on the nature of the infrastructure and how much of a barrier to groundwater flow it will create.

8.3.7 Two main sections have been identified as being below assumed groundwater level within the aquifer. Between Lavender Hill and the Heart of England Way, the route will be in the Park Lane cutting, the route will cut through the superficial deposits which are classified as a Secondary aquifer, and below the assumed groundwater level. However, the design will not include any significant impermeable barriers to groundwater flow and a small number of piles are proposed. Drainage systems will be provided, and so the additional groundwater flood risk is considered low.

8.3.8 Between the Pasture Farm accommodation overbridge and the East Way Loop underbridge (Diddington cutting), the route will cut through the top of the Mercia Mudstone, the top weathered zone can sometimes be water bearing and water strikes have been recorded in local borehole logs. However the design will include drainage systems, and there will not be any significant impermeable barriers to groundwater flow, pile foundations for the bridges are proposed, which would not significantly change the groundwater flood risk. Drainage systems will be provided.

Table 26: Summary of the conditions along the route corridor and areas where the groundwater flood risk may change

Approximate grid reference	**Title**	**Existing Ground Level (mOD)**	**Proposed level (mOD)**	**Assumed groundwater level(mOD)**	**Aquifer Classification (Superficial)**	**Aquifer Classification (Solid Geology)**	**Superficial Geology**	**Solid Geology (approximate depth, m) at reference borehole**	**Reference borehole**	**Distance to reference borehole BH (m)**	**Assumed ground level (mOD) at reference borehole**	**Assumed depth to groundwater level (m) at reference borehole**
SP2510 7671	Beachwood Underpass	112.6	120.7		Secondary A	Principal	Absent, though Alluvium near stream nearby	The Hill Mudstone (0)	Geol. map only		113	
SP2490 7701	Footpath Underpass 148+750	112.9	120.5	111.9		Principal	Absent	The Hill Mudstone/Sandstone band (0)	Geol. map only		114	1
SP2479 7717	Carol Green Rail Underbridge	110.9	120.2	109.9		Principal	Absent	The Hill Mudstone (0)	Geol. map only		111	1
SP2456 7752	Balsall Common viaduct	109.3	117.5	watercourse level	Secondary A	Principal	Alluvium close to stream approx. 100m each side	The Hill Mudstone (0 - 5)	Geol. map only		104-108	watercourse level
SP2399 7813	Lavender Hall Lane Overbridge	108.1	107.5	107.1	Secondary A	Principal	Absent but Glaciofluvial deposits nearby	The Hill Mudstone (0)	Geol. map only		108	1
SP2351 7859	Heart of England Way Bridge	113.3	102.9	112.3 assume perched in till	Secondary A	Secondary B	Till overlying Glaciofluvial deposits	Mercia Mudstone (5)	Geol. map only		113	1 assume perched in Till
SP2301 7920	Sixteen Acre Wood Bridge	108.7	101.3	98.7	Secondary A	Secondary B	Glaciofluvial deposits (sand/gravel)	Mercia Mudstone (20)	SP27NW38	260	108	10

Approximate grid reference	Title	Existing Ground Level (mOD)	Proposed level (mOD)	Assumed groundwater level(mOD)	Aquifer Classification (Superficial)	Aquifer Classification (Solid Geology)	Superficial Geology	Solid Geology (approximate depth, m) at reference borehole	Reference borehole	Distance to reference borehole BH (m)	Assumed ground level (mOD) at reference borehole	Assumed depth to groundwater level (m) at reference borehole
SP2236 8006	Marsh Farm viaduct	92	96.3	watercourse level	Secondary A	Secondary B	Alluvium over Glaciofluvial deposits (sand/gravel), possible seam of glacial clay	Mercia Mudstone (9)	SP28SW336	150	+91.3 at BH	watercourse level
SP2216 8028	Mercote Mill Farm Overbridge	92.6	93.4	84.6	Secondary A	Secondary B	Glaciofluvial deposits (sand/gravel)	Mercia Mudstone (10)	SP28SW336	200	94	8
SP2200 8053	A452 Kenilworth Road OB	91.5	91.9	88.5	Secondary A	Secondary B	Glaciofluvial deposits (sand/gravel)	Mercia Mudstone (5)	SP28SW333	400-600	92	3
SP2138 8186	River Blythe Bypass Overbridge	89.1	91.9	watercourse level	Secondary A	Secondary B	Alluvium (sand/gravel)	Mercia Mudstone (5)	SP28SW333	150	86-89	watercourse level
SP2164 8140	River Blythe viaduct	85.8	93.2	watercourse level	Secondary A	Principal	Alluvium (gravel/clay, peat and gravelly sand) 50m each side of watercourse. River Terrace deposits across rest of floodplain	Mercia Mudstone/Bromsgrove Sandstone (5?)	SP28SW73, SW28SW167		84-89	watercourse level
SP2123 8212	Diddington Lane OB	90.3	93			Secondary B	Absent	Mercia Mudstone (0)	Geol. map only		89	

Approximate grid reference	Title	Existing Ground Level (mOD)	Proposed level (mOD)	Assumed groundwater level(mOD)	Aquifer Classification (Superficial)	Aquifer Classification (Solid Geology)	Superficial Geology	Solid Geology (approximate depth, m) at reference borehole	Reference borehole	Distance to reference borehole BH (m)	Assumed ground level (mOD) at reference borehole	Assumed depth to groundwater level (m) at reference borehole
SP2106 8229	Shadow Brook viaduct	85.6	92.2	watercourse level	Secondary A	Secondary B	Alluvium - likely to be clay, sand and gravel	Mercia Mudstone (0 - 4)	Geol. map only		85-88.5	watercourse level
SP2094 8249	Pasture Farm Overbridge	98.8	90.5	97.8	Secondary A	Secondary B	Glaciofluvial deposits (sand/gravel)	Mercia Mudstone (3)	SP28SW327	120	98.5	1

8.4 Artificial sources / infrastructure

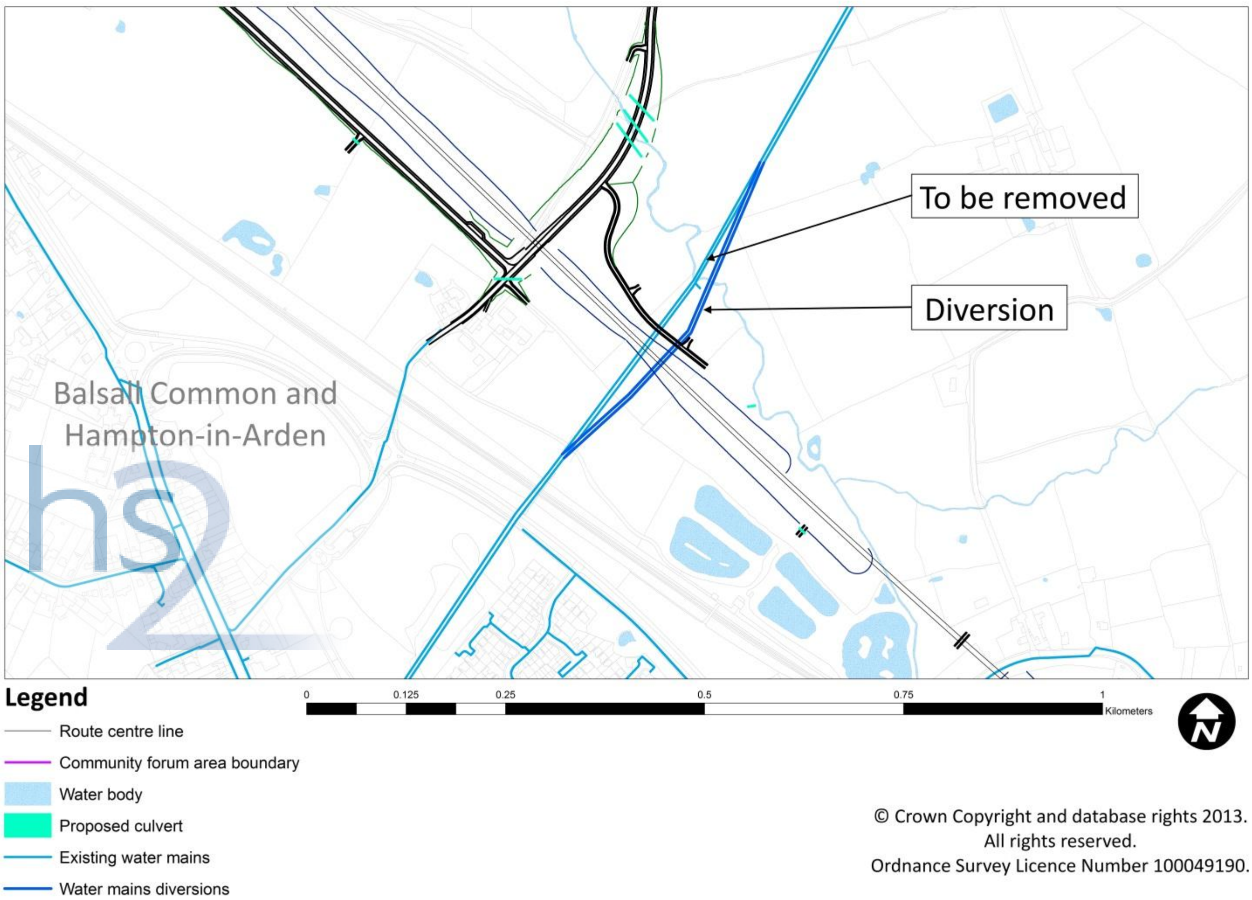
Water supply network

8.4.1 Overland flow has been adopted as a term in this section to distinguish it from surface water flooding i.e. where the capacity of the drainage system is exceeded. Overland flow in this section refers to flow over the surface which is caused by infrastructure failure.

8.4.2 Assets are mapped and where appropriate the potential overland flow paths inspected by interrogation of topographic data. The extent of overland flow from a pipe failure will depend on discharge rate which is in turn influenced by a number of factors including water main diameter, pressure, depth and upstream water source. Given the limited data available and complexity in accurately assessing overland flow routes this FRA is limited to identification of potential flow paths only.

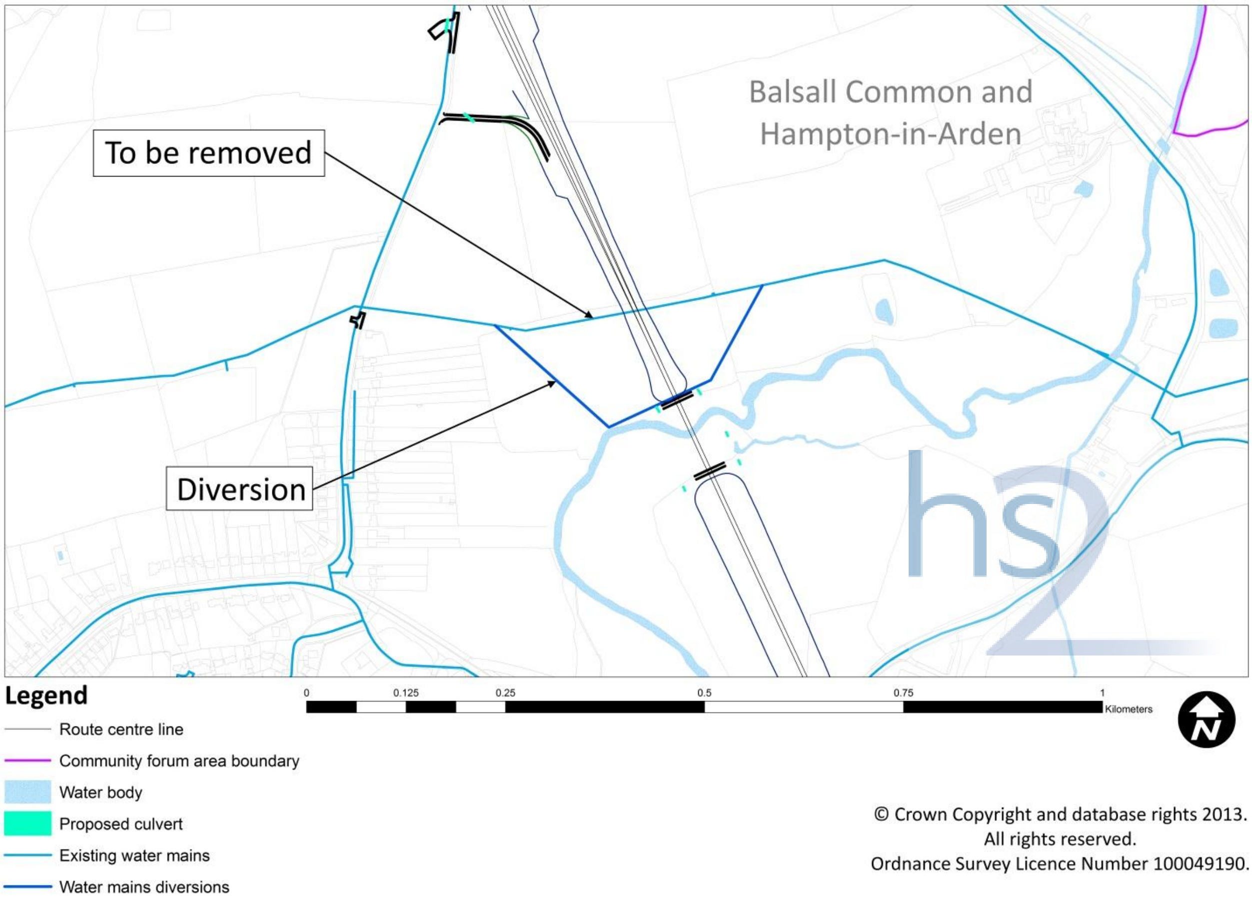
8.4.3 Where existing or diverted water mains and water distribution infrastructure have been judged to offer a potential source of flood risk from an upstream catchment an assessment of potential surface water flow routes have been made of the risk associated with this source.

Figure 23: Balsall Common diversion



8.4.4 Two existing water mains at Balsall Common will be diverted to avoid the proposed route and cross under the viaduct. Local topography suggests that in the event of failure, water will be received by Bayleys Brook and the proposed surface water cut-off ditches at the toe of proposed route embankments. No resulting surface water interface with either the Proposed Scheme or local buildings is anticipated east of the proposed works and embankment drainage would collect any run-off from the west.

Figure 24: Blythe Valley diversion



8.4.5 The existing 1200mm diameter water main at Blythe Valley will be diverted to avoid the proposed route and cross under the viaduct. A further diversion of an existing water main <200mm in diameter is also proposed through this viaduct from Meriden Road and is indicated on Figure 24. Local topography suggests that in the event of failure, water would be received by the River Blythe. No resulting surface water interface with either the Proposed Scheme or local buildings is anticipated east of the proposed works and land drainage would collect any runoff from west of Meriden Road / Diddington Lane diversion.

Reservoirs/large water bodies

8.4.6 The proposed overland flow routes associated with reservoir failure have been compared to the Proposed Scheme. The overland flow routes are discussed in the following sections in relation to the reservoir sources and the Proposed Scheme development.

Earlswood lakes

8.4.7 The flood pathway from these lakes will convey water along the River Blythe channel to the River Blythe viaduct approximately 26km downstream from the lakes. The Environment Agency's reservoir flood inundation mapping indicates a floodplain which appears no more extensive than the predicted 1% AEP plus CC flood map. It is assumed that the river modelling of the River Blythe viaduct provides adequate assessment of risk posed to the Proposed Scheme from failure of these reservoirs. Further assessment is recommended in the form of a review of the asset owners Reservoir Emergency Plan which may contain more accurate assessment of downstream flood risk and proposals for flood warnings.

Meriden Service reservoirs

8.4.8 The flood pathway from these reservoirs will convey water through the River Blythe Bypass channel, beneath the diverted A452 Kenilworth Road and northwards into the River Blythe. A proportion of the flow may be conveyed along the Bypass channel and beneath the route on Blythe Bypass viaduct. The floodplain extent from these reservoirs is less than that predicted for a 1% AEP event on the Environment Agency's Flood Mapping. It is assumed that the river modelling of the River Blythe viaduct provides adequate assessment of risk posed to the Proposed Scheme from failure of these reservoirs.

8.4.9 Further assessment is recommended in the form of a review of the asset owners Reservoir Emergency Plan which may contain more accurate assessment of downstream flood risk and proposals for flood warnings.

Geary's Level and Molands lakes

8.4.10 The flood pathway from these reservoirs would convey water directly to the River Blythe without passing through any of the Proposed Scheme. However, the proximity of the reservoirs to the Blythe may result in flood risk impact to the proposed new B4102 Meriden Road diversion junction located on the A452 Kenilworth Road. The floodplain extent from the reservoir failure mapping is similar in extent to the Environment Agency's flood mapping and while baseline modelling undertaken for the Blythe Bypass indicates an increase in flood extent at the same location it is assumed that the reservoir flood extent would not be significantly greater than the 1% AEP plus CC event. It is therefore assumed that the river modelling of the River Blythe viaduct provides adequate assessment of risk posed to the Proposed Scheme from failure of these reservoirs.

8.4.11 Further assessment is recommended in the form of a review of the asset owners Reservoir Emergency Plan which may contain more accurate assessment of downstream flood risk and proposals for flood warnings.

8.5 Summary of potential impacts on flood risk

8.5.1 Reference should be made to the flood maps provided in Volume 5: Map book WR-05. A summary of main receptors is provided in Table 27.

Table 27: Summary of potential flood risk impacts in CFA23

Receptor	Vulnerability Classification	Pathway	Impacts
General Proposed Scheme		Rivers	The route is located on embankment and viaduct. Embanked sections are in Flood Zone 1 and as such will not cause a significant increase in flood risk. Where the route spans Flood Zones 2 and 3 viaducts will be employed or replacement floodplain storage will be provided and following implementation of all mitigation measures no significant increase in flood risk is identified.
		Surface water and drainage systems	Cuttings will be protected from surface water flooding by cut-off ditches and flood protection mound.
		Groundwater	Proposed Scheme will be in cutting north of Balsall Common. Groundwater seepage is not envisaged to be significant. Groundwater will be intercepted by Proposed Scheme rail drainage system.
		Artificial Bodies	Flood waters released by the failure of the artificial water bodies identified in this CFA would flow along the River Rea and River Tame. There would not be any increased risk of flooding from artificial sources caused by the Proposed Scheme
River Blythe			
B4102 Meriden Road	Less vulnerable	River FZ3b	Increase (up to 60mm) in existing flooding on B4102 Meriden Road. No change in hazard rating..
Meriden Mill Farm	More vulnerable	River FZ3b	No change in flood risk
A452 Kenilworth Road	More vulnerable	River FZ3b	No change in flood risk
Mouldings Green Farm	More vulnerable	River FZ3b	No change in flood risk
Agricultural Land	Less vulnerable	River FZ3b	Increase in existing flooding of between 20 to 60mm with a localised area of increase up to 170mm immediately upstream of the Proposed Scheme over agricultural land. Minor increase in extents.
SSSI		River	No significant impact.
Shadow Brook			
Diddington Lane	Less vulnerable	River FZ3b	Diddington Lane to be stopped up and existing culvert removed

Receptor	Vulnerability Classification	Pathway	Impacts
A452 Kenilworth Road	More vulnerable	River FZ3a	Minor increase in flow at theA452Kenilworth Road but no resultant increase in flood levels.
Agricultural Land	Less vulnerable	River FZ3b	Slight reduction in flood levels upstream of the Shadow Brook bridge crossing
Bayleys Brook – Balsall Common			
Agricultural Land	Less vulnerable	River FZ3b	Localised increases in downstream flood level up to 150mm with minimal increase in floodplain extent
Lavender Hill Fisheries	Less vulnerable	Above River FZ3a	No significant change in flood risk
Truggist Lane	Less vulnerable	Model not extended to assess flood risk to Truggist Lane	There is no increase in flood level at the upstream model extent which is located downstream of Truggist Lane
Bayleys Brook – Marsh Farm			
A452 Kenilworth Road	More vulnerable	Above FZ3a flood levels	No change in flood risk
Marsh Lane	Less vulnerable	Above FZ3a flood levels	Less than 10mm increase in downstream flood levels
Berkswell Marsh SSSI	Water compatible	River FZ3b	No change in flood risk
Mercote Lodge	More vulnerable	Marginally Outside of River FZ3a	Less than 10mm increase in downstream flood levels
Agricultural Land	Less Vulnerable	River FZ3	Localised increase in depths immediately downstream of the Proposed Scheme.
Bayleys Brook – Lavender Hall Lane			
Lavender Hall Lane	Less vulnerable	Above River FZ3a levels	Slight increase in flood levels upstream of the Lavender Hall Lane crossing. The road level will be higher and level of flood protection to Lavender Hall Lane is increased.
Agricultural Land	Less vulnerable	River FZ3b	Minor, localised increase (approximately 40mm) in flood levels upstream of Lavender Hall Lane
Horn Book / River Blythe Tributary			
Marsh Lane	Less vulnerable	Above FZ3a flood levels	No change in flood risk
Agricultural Land	Less vulnerable	River FZ3b	No change in flood risk
A452 Kenilworth Road	More vulnerable	Above River FZ3a levels	No change in flood risk, road levels are increased

Receptor	**Vulnerability Classification**	**Pathway**	**Impacts**
Superficial deposits overlying the Tile Hill Mudstone and Mercia Mudstone from Lavender Hall Lane overbridge to the Heart of England Way bridge.	Less vulnerable	Groundwater	Rail level along route is below groundwater levels, with mitigation provided by drainage systems.
Superficial deposits overlying the Mercia Mudstone at Pasture Farm overbridge	Less vulnerable	Groundwater	Rail level along route is below groundwater levels, with mitigation provided by drainage systems.
Birmingham to Rugby Line	Essential infrastructure	Bayleys Brook	No change in flood risk. Balsall Common viaduct will be sized appropriately and replacement floodplain storage will be provided.
Truggist Lane	Less vulnerable	Bayleys Brook	No change in flood risk. Balsall Common viaduct will be sized appropriately and replacement floodplain storage will be provided.
Lavender Hall Lane diversion	Less vulnerable	Bayleys Brook	Elevation of Lavender Hall Lane will be raised to pass over Proposed Scheme. Flood alleviation culverts and replacement floodplain storage will be provided.
Kenilworth Road diversion	More vulnerable	Horn Brook	Elevation of Kenilworth Road will be raised to pass over Proposed Scheme. Replacement floodplain storage will be provided.

9 Conclusion

9.1.1 This FRA accounts for the flood risk considerations caused by construction of the Proposed Scheme within CFA23 to the proposed route and third parties.

9.1.2 In order to fully understand the existing risk posed by the River catchment and to be able to evaluate the impact of the Proposed Scheme infrastructure on the hydraulic behaviour of the Blythe Catchment a number of discrete hydraulic models have been created using either fully two dimensional (TUFLOW) models or one dimensional steady state models (HEC-RAS). The Environment Agency does not have an existing model of the Blythe catchment.

9.1.3 Hydraulic models were created for each watercourse crossing where the 1% AEP+ 20% CC exceeded $3m^3/s$. Simplified culvert calculations based on C689 were used to assess the post development flood risk impact of smaller watercourses.

9.1.4 The Proposed Scheme infrastructure proposals have been incorporated into the baseline river models in order for the impact of the proposals on flood risk to be determined.

9.1.5 The Proposed Scheme will be designed to be resilient up to and including the 0.1% AEP storm event. This will be achieved by either setting the rail level at 1m above the 0.1% AEP flood level or by protecting the route using flood defence structures set at a level that is equivalent to 300mm above the 0.1% return AEP flood level.

9.1.6 The surface water management strategy for CFA23 ensures run-off generated by rain water falling onto the Proposed Scheme is collected, attenuated and discharged at a controlled rate. The strategy is designed to manage discharges generated by rain storm events with a 1% AEP plus a 30% increase in rainfall intensity to allow for changes in rainfall patterns due to climate change.

10 References

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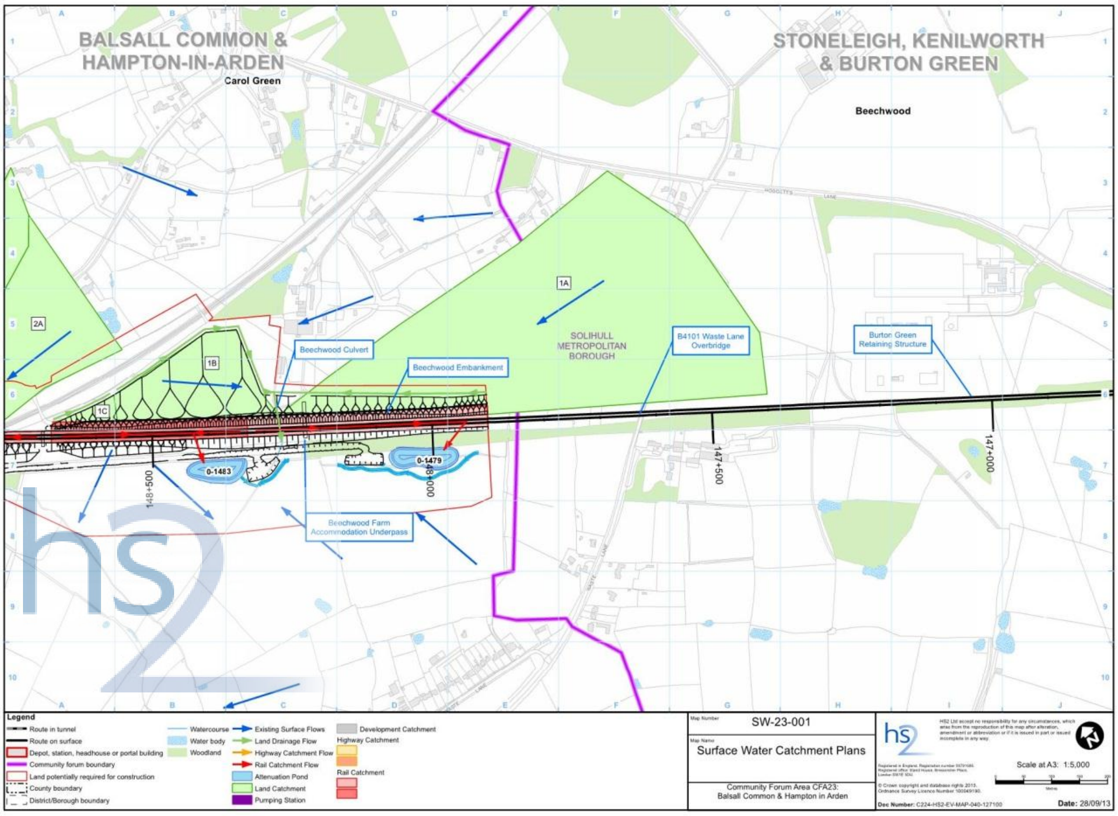
11 Annex A

11.1 Surface water catchment flow figures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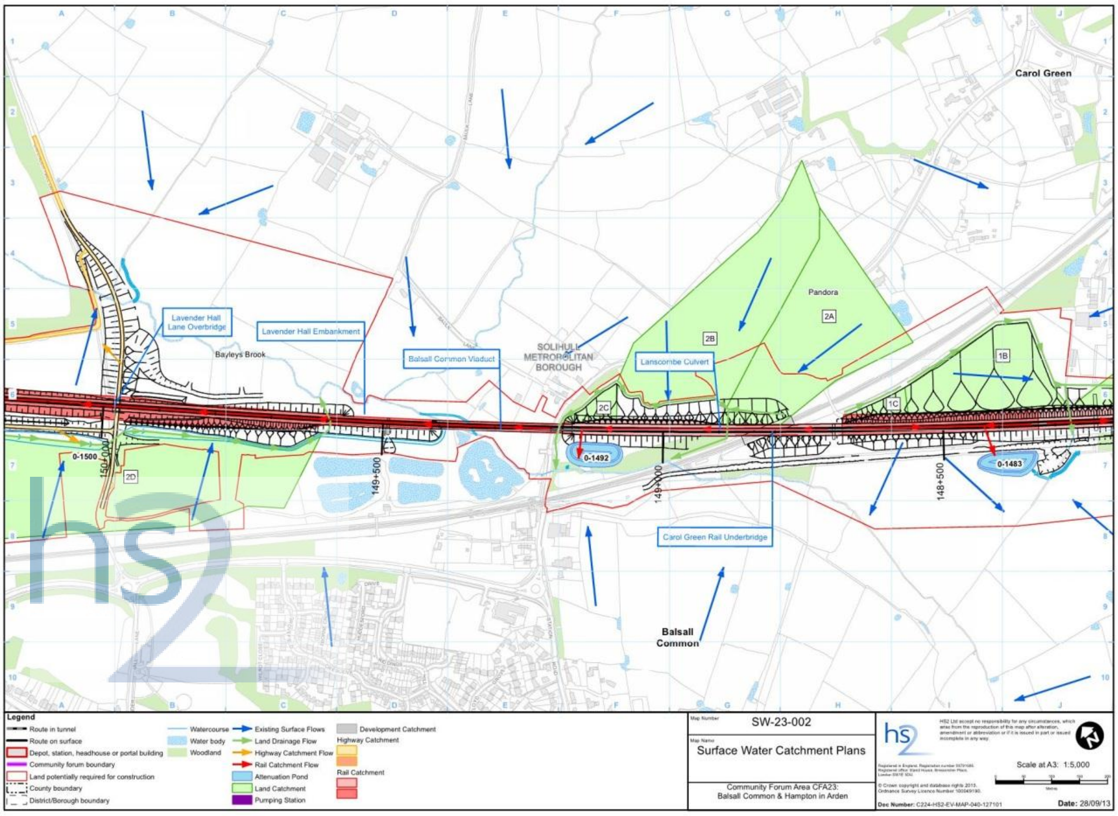
STONELEIGH, KENILWORTH & BURTON GREEN
Carol Green
Beechwood
Beechwood Culvert
Beechwood Embankment
SOLIHULL METROPOLITAN BOROUGH
B4101 Waste Lane Overbridge
Burton Green Retaining Structure
Beechwood Farm Accommodation Underpass
148+500
148+000
147+500
147+000
SW-23-001
Surface Water Catchment Plans
Community Forum Area CFA23: Balsall Common & Hampton in Arden
Scale at A3: 1:5,000
Date: 28/09/13


Carol Green
Pandora
Lavender Hall Lane Overbridge
Lavender Hall Embankment
Bayleys Brook
Balsall Common Viaduct
SOLIHULL METROPOLITAN BOROUGH
Lanscombe Culvert
Carol Green Rail Underbridge
Balsall Common
150+000
149+500
149+000
148+500
SW-23-002
Surface Water Catchment Plans
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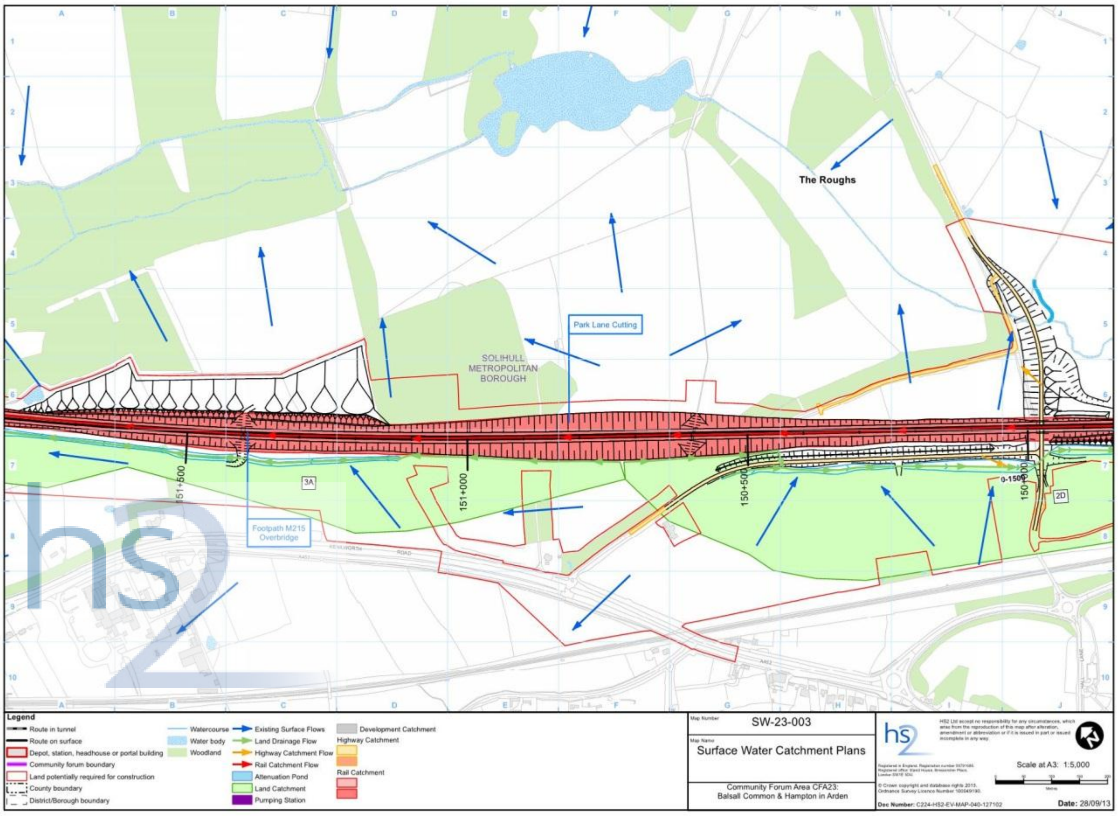
The Roughs
Park Lane Cutting
SOLIHULL METROPOLITAN BOROUGH
Footpath M215 Overbridge
151+500
151+000
150+500
150+000
3A
2D
Legend
SW-23-003
Surface Water Catchment Plans
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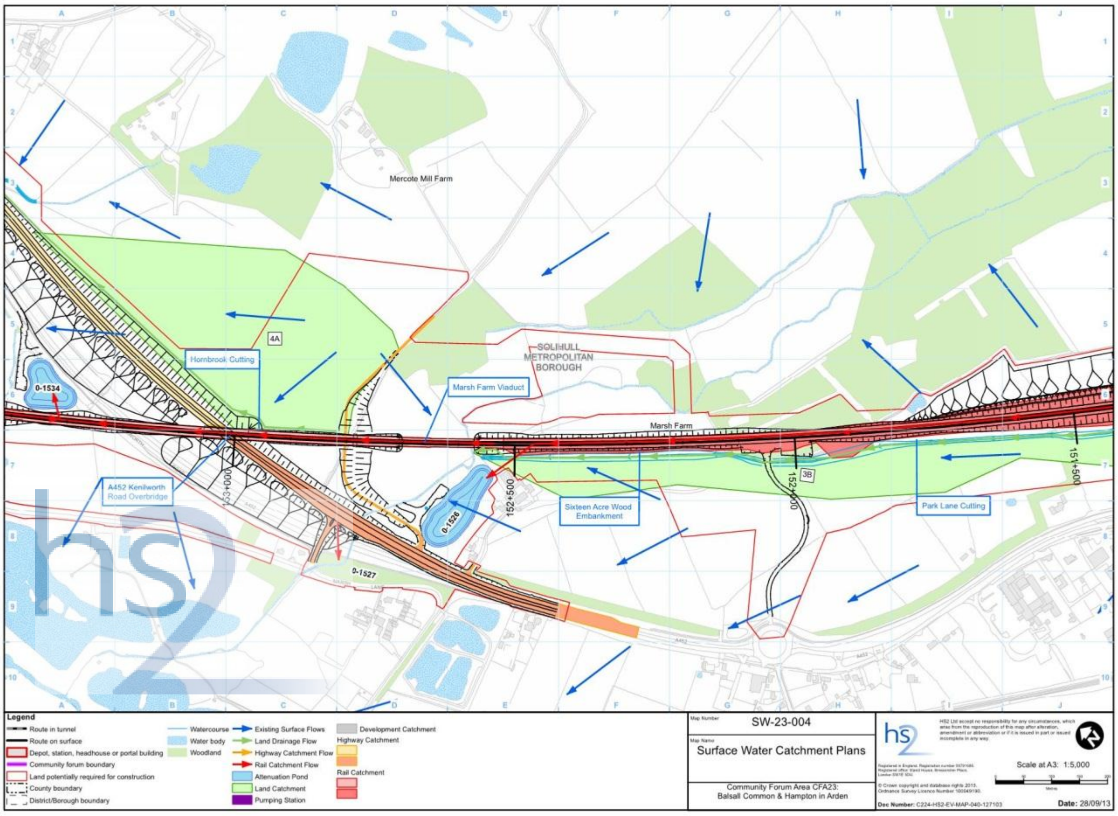
Mercote Mill Farm
Hornbrook Cutting
Marsh Farm Viaduct
SOLIHULL METROPOLITAN BOROUGH
Marsh Farm
A452 Kenilworth Road Overbridge
Sixteen Acre Wood Embankment
Park Lane Cutting
153+000
152+500
152+000
151+500
4A
3B
Legend
SW-23-004
Surface Water Catchment Plans
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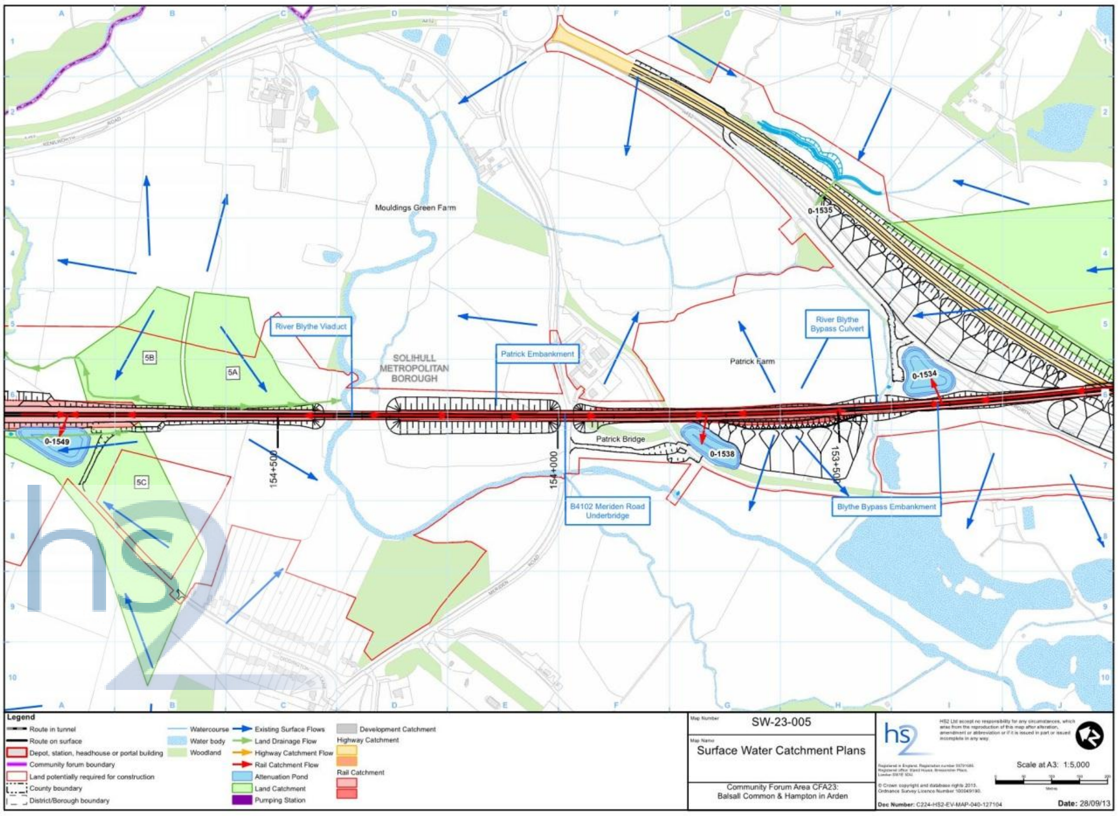
Mouldings Green Farm
River Blythe Viaduct
Patrick Embankment
SOLIHULL
METROPOLITAN
BOROUGH
River Blythe
Bypass Culvert
Patrick Farm
0-1535
0-1534
0-1549
0-1538
Patrick Bridge
154+500
154+000
153+500
B4102 Meriden Road
Underbridge
Blythe Bypass Embankment
5A
5B
5C
Legend
Route in tunnel
Route on surface
Depot, station, headhouse or portal building
Community forum boundary
Land potentially required for construction
County boundary
District/Borough boundary
Watercourse
Water body
Woodland
Existing Surface Flows
Land Drainage Flow
Highway Catchment Flow
Rail Catchment Flow
Attenuation Pond
Land Catchment
Pumping Station
Development Catchment
Highway Catchment
Rail Catchment
SW-23-005
Surface Water Catchment Plans
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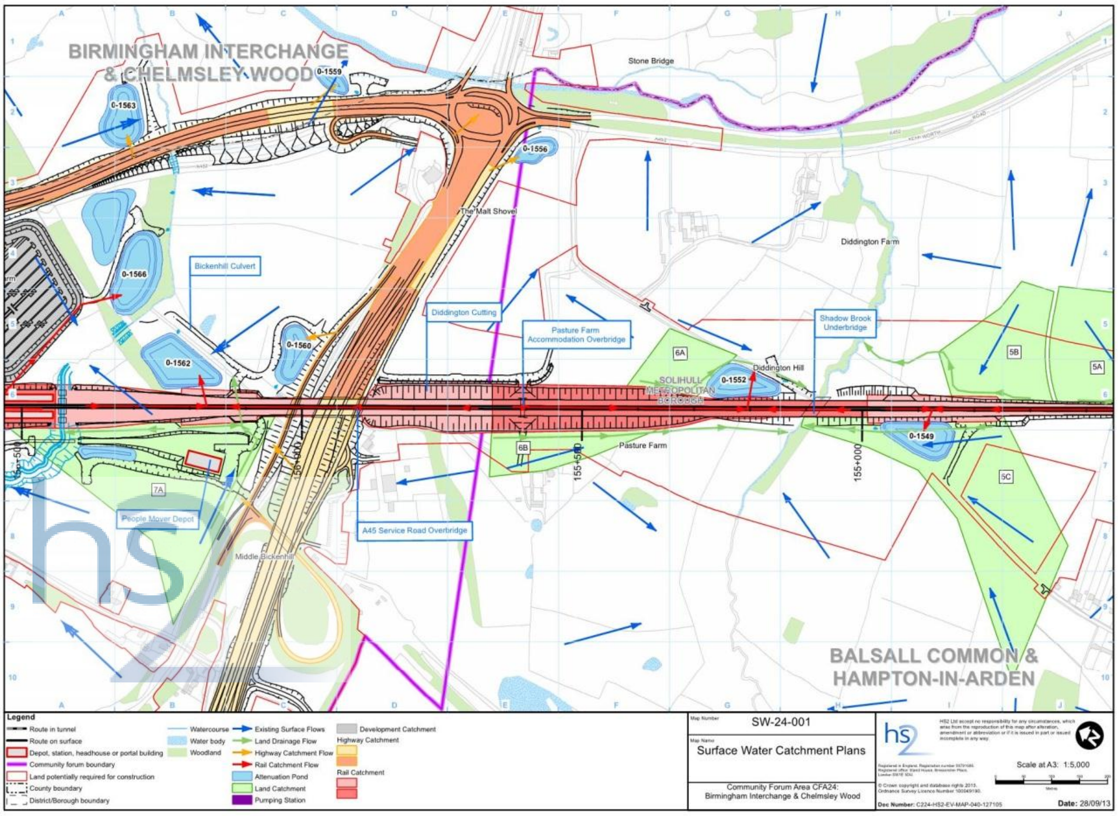
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& CHELMSLEY WOOD
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0-1563
0-1556
Stone Bridge
The Malt Shovel
Diddington Farm
0-1566
Bickenhill Culvert
Diddington Cutting
Pasture Farm
Accommodation Overbridge
Shadow Brook
Underbridge
0-1560
0-1562
6A
SOLIHULL
METROPOLITAN
BOROUGH
0-1552
Diddington Hill
5B
5A
0-1549
6B
155+500
155+000
Pasture Farm
7A
People Mover Depot
A45 Service Road Overbridge
Middle Bickenhill
5C
BALSALL COMMON &
HAMPTON-IN-ARDEN
Legend
Route in tunnel
Route on surface
Depot, station, headhouse or portal building
Community forum boundary
Land potentially required for construction
County boundary
District/Borough boundary
Watercourse
Water body
Woodland
Existing Surface Flows
Land Drainage Flow
Highway Catchment Flow
Rail Catchment Flow
Attenuation Pond
Land Catchment
Pumping Station
Development Catchment
Highway Catchment
Rail Catchment
SW-24-001
Surface Water Catchment Plans
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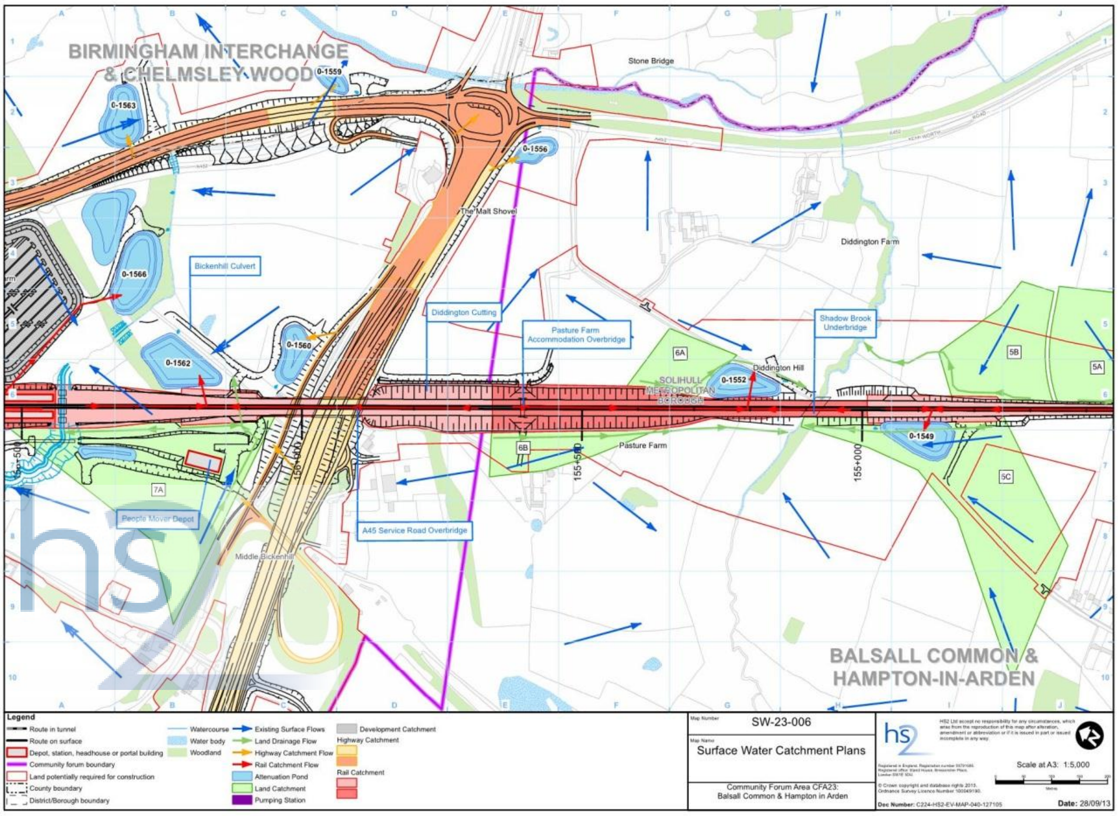
BIRMINGHAM INTERCHANGE & CHELMSLEY WOOD
BALSALL COMMON & HAMPTON-IN-ARDEN
Stone Bridge
The Malt Shovel
Diddington Farm
Bickenhill Culvert
Diddington Cutting
Pasture Farm Accommodation Overbridge
Shadow Brook Underbridge
Diddington Hill
SOLIHULL METROPOLITAN BOROUGH
Pasture Farm
People Mover Depot
A45 Service Road Overbridge
Middle Bickenhill
0-1559
0-1563
0-1556
0-1566
0-1562
0-1560
0-1552
0-1549
6A
6B
5A
5B
5C
7A
155+500
155+000
Legend
Route in tunnel
Route on surface
Depot, station, headhouse or portal building
Community forum boundary
Land potentially required for construction
County boundary
District/Borough boundary
Watercourse
Water body
Woodland
Existing Surface Flows
Land Drainage Flow
Highway Catchment Flow
Rail Catchment Flow
Attenuation Pond
Land Catchment
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